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POTENTIAL MARKETS FOR PARTICLEBOARD PRODUCED IN THE ROCKY MOUNTAINS

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POTENTIAL MARKETS FOR PARTICLEBOARD PRODUCED IN THE ROCKY MOUNTAINS

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POTENTIAL MARKETS FOR PARTICLEBOARD PRODUCED IN THE ROCKY MOUNTAINS

Particleboard is defined in Commercial Standard CS236-66 as, "A panel material composed of small discrete pieces of wood bonded together in the presence of heat and pressure by an extraneous binder" (National Bureau of Standards, 1966). There are basically two methods of manufacturing this product based on the type of pressure applied. "When the pressure is applied in the direction perpendicular to the faces as in a conventional multi-platen hot press, they are defined as 'flat-platen pressed,' and when the applied pressure is parallel to the faces, they are defined as 'extruded' (National Bureau of Standards, 1966)." U. S. production of particleboard is almost exclusively by the multi-platen process, therefore, this report will not consider production by the extrusion process.

There are only three particleboard mills in the entire Rocky Mountain region (Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico) and these are Pack River Co., Sandpoint, Idaho; Mexwood Products, Albuquerque, New Mexico; and Southwest Forest Industries, Flagstaff, Arizona. The total production of these three mills was 77 million square feet on a 3/4-inch basis, or 3 percent of the total industry capacity, in 1970 (Staepelaere, 1971). Although a technical potential exists for particleboard production in the Black Hills and elsewhere in the central and eastern Rocky Mountains, none is being produced in that portion of the region at the present time. The question arises as to whether it would be economically feasible to initiate production and whether such production would result in a net benefit to the region, its local communities, and the management of its forest resources.

Primary marketing areas for Rocky Mountain produced particleboard would appear to be the Rocky Mountain region as previously defined and the Midwest. There exists in these regions a demand for particleboard in considerable excess of that filled by resident mills (Staepelaere, 1971). Since production capacity has generally outrun demand in the particleboard industry, successful

market competition would undoubtedly require lower raw material costs, greater production efficiency, lower transportation costs, favorable product differentiation, or a combination of these. A Rocky Mountain producer competing with producers in other particleboard-producing centers such as the West Coast, South, or Lake States seems most likely to achieve the last two of these potential advantages--lower transportation costs and/or favorable product differentiation.

Four timber species of importance to particleboard manufacturers and potential manufacturers in the Rocky Mountain region are ponderosa pine, Engelmann spruce, lodgepole pine, and aspen. All of these species are potentially suitable for particleboard manufacture and are thought to be among the more desirable raw materials for this product. Substantial volumes of these species exist in the form of processing residues, woods residues, and small roundwood that should be removed to improve timber stands. Raw material in any of these forms is technically suitable for particleboard manufacture. An analysis of the utilization of wood-residue in the United States by Lewis (1965) pointed out that of the coarse residue not being used (40 percent of total unused residue) about 75 percent is of the softwood variety originating mainly in the Rocky Mountain area. Further, it may be advantageous to divert to local particleboard manufacture part or all of the residues now being exported to the Lake States for pulp production.

The principal questions to be answered by this study are whether or not sufficient markets can be developed to provide an economic outlet for particleboard that could be produced in the central or eastern Rocky Mountain region. If such markets can be developed, what is their prospective size and what would be their product requirements?

To answer these questions it will be necessary to consider the technical properties of particleboard that could prospectively be made from raw materials available in Rocky Mountain areas -- i.e., ponderosa pine, Engelmann spruce, lodgepole pine, and aspen -- in both residue and roundwood form. Particular emphasis on the technical properties of specialty products that could be produced will be needed.

To define prospective markets it will be necessary to look beyond current uses to determine trends in particleboard market volumes and applications. Entirely new uses may be foreseen, particularly as related to industrialized housing production.

The search for markets will be limited in this study to Rocky Mountain and Midwest market areas.

The overall study is divided into two self-contained, but related, phases. Phase I with which this report is concerned consists of collecting and analyzing existing information pertaining to the study objectives. Phase II will develop additional information and provide predictions of marketing and technical changes likely to occur in the particleboard field through 1985.

Objectives

The objectives of this study are to determine from secondary data[1/] whether markets can be established for Rocky Mountain particleboard products and the volumes and kinds of products that could logically be absorbed by Rocky Mountain and Midwest markets.

More specifically the study objectives include:

1. An evaluation of the technical properties of particleboards made from ponderosa pine, Engelmann spruce, lodgepole pine, and aspen by various processes.
2. A comparison of the technical properties among particleboards made from these species, their advantages and disadvantages.
3. A comparison of the technical properties of particleboards made from these species with other commercial particleboards.

1/ Secondary data as used here comprises published and unpublished material available from a variety of sources including governmental agencies, industry associations, and our own research files.

4. A survey of widely used specifications and model code requirements for particleboard products marketed in Rocky Mountain and Midwest areas.

5. Definition of Rocky Mountain and Midwest areas that appear to be the best markets for Rocky Mountain produced particleboard.

6. Determination of the structure, conduct, and performance of existing and currently planned particleboard markets in the defined areas.

7. An estimation of volumes presently consumed in the defined market areas by type and end use.

8. An evaluation of price and other competitive factors relative to alternative materials.

9. Determination of transportation advantages and disadvantages of Rocky Mountain producers with respect to West Coast, southern, and Lake States producers in shipments to the defined market areas.

10. Recommendations as to additional research required to clarify and expand knowledge of particleboard marketability in Rocky Mountain and Midwest markets.

Introduction to Technical Properties of Particleboard

The National Particleboard Association (NPA) serves in the capacity of spokesman for particleboard manufacturers that account for over 80 percent of the total industry production.

> "The prime purpose of the organization is to encourage high standards of product quality and performance and to promote broader use of particleboard" (National Particleboard Association, 1967).

The U. S. Department of Commerce, National Bureau of Standards, Office of Product Standards has, with the cooperation of the NPA, established a

recorded voluntary standard for mat-formed particleboard -- Commercial Standard CS236-66 (National Bureau of Standards, 1966). In this standard are tabulated the technical property requirements of particleboard. The member mills of the NPA assure the consumer of a satisfactory product within the specific property limitations as listed in Table 1.

Important Particleboard Properties

Density is weight per unit volume commonly expressed in pounds per cubic foot at an acceptable moisture content of less than 10 percent. Modulus of Elasticity is a measure of resistance to deflection under an applied load. It is an indication of the stiffness of a panel and expressed in pounds per square inch (psi). Modulus of Rupture is a measure of bending strength (psi). Internal Bond measures the force two faces of a panel will withstand before pulling apart. It is a measure of the strength of the bond between individual particles within the panel and is expressed in pounds per square inch (psi). Screw Holding represents the force needed to pull out a No. 10, type A sheet metal screw under specified conditions of test. Face and edge test values are those commonly reported and they are expressed in pounds (lbs.). Linear Expansion measures the change in dimension in the plane of a board in response to a change in relative humidity from 50 to 90 percent and is expressed in percent.

The above properties of particleboard will receive the most attention in this report although moisture absorption and thickness swelling will receive some consideration. Another property that will be briefly mentioned is thermal conductivity.

Particleboard Manufacturing Variables

The variables involved in the manufacture of particleboard are numerous and generally considered to number somewhere in the neighborhood of 30. The wood species used as the basic raw material is an important variable in the manufacturing process. Unfortunately, this variable has received extremely limited examination by researchers in the particleboard field. An extensive review of the particleboard literature has failed to develop any direct relationships between final board properties and the species of wood used as the raw material, although development of species comparisons is believed possible in an indirect manner.

TABLE 1. Property Requirements

TYPE (USE)	DENSITY (GRADE) (min. avg.)	CLASS [3]	MODULUS OF RUPTURE (min. avg.)	MODULUS OF ELASTICITY (min. avg.)	INTERNAL BOND (min. avg.)	LINEAR EXPANSION (max. avg.)	SCREW HOLDING	
							FACE (min. avg.)	EDGE (min. avg.)
			psi	psi	psi	percent	lbs.	lbs.
1.[1]	A (High Density, 50 lbs/cu ft and over)	1	2400	350,000	200	0.55	450	----
		2	3400	350,000	140	0.55	----	----
	B (Medium Density, between 37 and 50 lbs/cu ft)	1	1600	250,000	70	0.35	225	160
		2	2400	400,000	60	0.30	225	200
	C (Low Density, 37 lbs/cu ft and under)	1	800	150,000	20	0.30	125	----
		2	1400	250,000	30	0.30	175	----
2.[2]	A (High Density, 50 lbs/cu ft and over)	1	2400	350,000	125	0.55	450	----
		2	3400	500,000	400	0.55	500	350
	B (Medium Density, between 37 and 50 lbs/cu ft)	1	1800	250,000	65	0.35	225	160
		2	2500	450,000	60	0.25	250	200

[1] Type 1.—Mat-Formed particleboard (generally made with urea-formaldehyde resin binders) suitable for interior applications.

[2] Type 2.—Mat-Formed particleboard made with durable and highly moisture and heat resistant binders (generally phenolic resins) suitable for interior and certain exterior applications when so labeled.

[3] Class —Strength classifications based on properties of panels currently produced.

(National Bureau of Standards, 1966)

A selected bibliography was prepared as a part of this study. This bibliography contains brief abstracts of articles considered pertinent to this report in that they contain information about the study species in particleboard or related research considered applicable to the entire particleboard spectrum. This bibliography has been submitted separately from this report.

One author who has discussed the species variation problem is William G. Foster (1967). He reports that "the subject of species variation can take a two-fold division, that is, (1) the variations encountered from species to species, and (2) those variations within a species."

According to Foster, some major species variables include the following:

1. Density - the most important species variable. Generally speaking, the lower density woods will produce panels within present desired specific gravity ranges and usually with superior strength properties when compared to the high density woods. (Foster did not define what he considered low and high densities. He only implied that this is the reason for the popularity of the coniferous species). This is usually attributed to the greater compression factor on each particle necessary in using the lower density woods and the resulting stronger adhesive bonds. Variation of density within a species can cause problems in daily production.

2. Acidity - an important species variable on which considerable research has been conducted because of the effects of acidity on the resins used in the manufacture of particleboard.

3. Moisture content - this variable influences the machining and drying phases of manufacture and is usually considered in the design of the plant's equipment.

4. Extractives - the extractives and their variations play an important part in the consumption of resin and its curing rate. Little research related to extractives in the particleboard manufacturing process has been reported in the literature.

Other less important variables discussed by Foster include foreign matter (bark, mineral matter, and metallic particles), growth location, seasonal changes, and supplier's practices.

Another author (Marra, 1958) has stated that the nature of the raw materials may be a deciding factor in determining the board to be produced at a given location. Although Marra was primarily referring to particle geometry and condition, the implication of species differences is also apparent.

Technical Properties of Particleboard Made From Rocky Mountain Species

To determine the kinds of particleboard products that could logically be produced from Rocky Mountain ponderosa pine, Engelmann spruce, lodgepole pine, and aspen, an evaluation of the technical properties of particleboards made from these species was made. Although there is a lack of published literature on the properties of interest for these species, some related literature is available (Anderson et al., 1961; Arsenault, 1964; Forest Industries, 1967; Gerad, 1966; Gertjejansen, 1969; Larmore, 1959; Mueller, 1959; Nixon, 1953; Patton, 1953; and Stayton et al., 1971). The Colorado State University Forest and Wood Sciences Department has for several years been conducting various studies on particleboard made from lodgepole pine and Engelmann spruce furnish (Bowen, 1967a, b). This research points to the general conclusion that these species appear well-suited for the manufacture of a wide range of board densities using both urea-formaldehyde and phenol-formaldehyde resins.

Specific research projects conducted at the Colorado State University Wood Science Laboratory will be discussed below for Engelmann spruce and lodgepole pine particleboards. It is recommended that a more complete development of properties attainable by using ponderosa pine and aspen be carried out by questioning manufacturers currently using these species. The same approach may be useful for obtaining specific mechanical property information on Douglas-fir and southern pine particleboards although this may not be necessary because of the extensive literature on these species that could be

analyzed and combined into a useable format for comparison with the Rocky Mountain species. A limited attempt at this approach will be made in this report.

Particleboard studies at the Colorado State University Wood Science Laboratory have developed the following general relationships that allow comparisons between the O.D. density (lb./ft.^{3}) of Engelmann spruce particleboards bonded with urea resin and the properties MOR, MOE, screw holding, thickness swelling, water absorption, internal bond and tensile strength. An 8:00 minute presstime was used in conjunction with a range of resin contents--3, 4-¼; 5-½, 7-¼, and 8 percent--to manufacture boards ranging in density from approximately 23 lb./cu.ft. to 40$^+$ lb./cu.ft. All boards were pressed to ½-in. thickness from stock prepared on a laboratory flaker. A uniform flake .018-in. thick by 3/4-in. length and 1/8-in. width was produced by the flaker. The flakes were conditioned to 3 percent moisture content before spraying with resin. Each property mentioned above was plotted on the y-axis against the final board density on the x-axis. Also shown on each graph are data (diagonally hatched area) for 5 commercial boards ranging in density from 38-43 lb./ft.^{3} The results are presented in Figures 1 - 7.[2/]

As may be discerned from Figures 1 - 7, there appears to be a direct relationship between the O.D. density of Engelmann spruce particleboard and its MOR, MOE, screw-holding capacity, thickness swell, internal bond and tensile strength and an inverse relationship between O.D. density and water absorption. Some of these relationships falter at the higher levels of density. In interpreting water absorption and thickness swell, it should be recognized that these laboratory-made boards included no water repellent or sizing material. Practical application of the above relationships is that a species capable of being manufactured into a wide range of board densities will also yield a wide range of physical and mechanical properties to suit specific needs of a consumer. These relationships will also be used later in this report in a comparison with Douglas-fir and southern pine particleboards. Under comparable conditions of pressing to different densities, lodgepole pine boards showed greater sensitivity to resin content than did Engelmann spruce. Other

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2/ Figures 1 - 7 were prepared by Dr. H. E. Troxell, Professor of Wood Science at Colorado State University, under whose direction all Colorado State University particleboard research has been conducted.

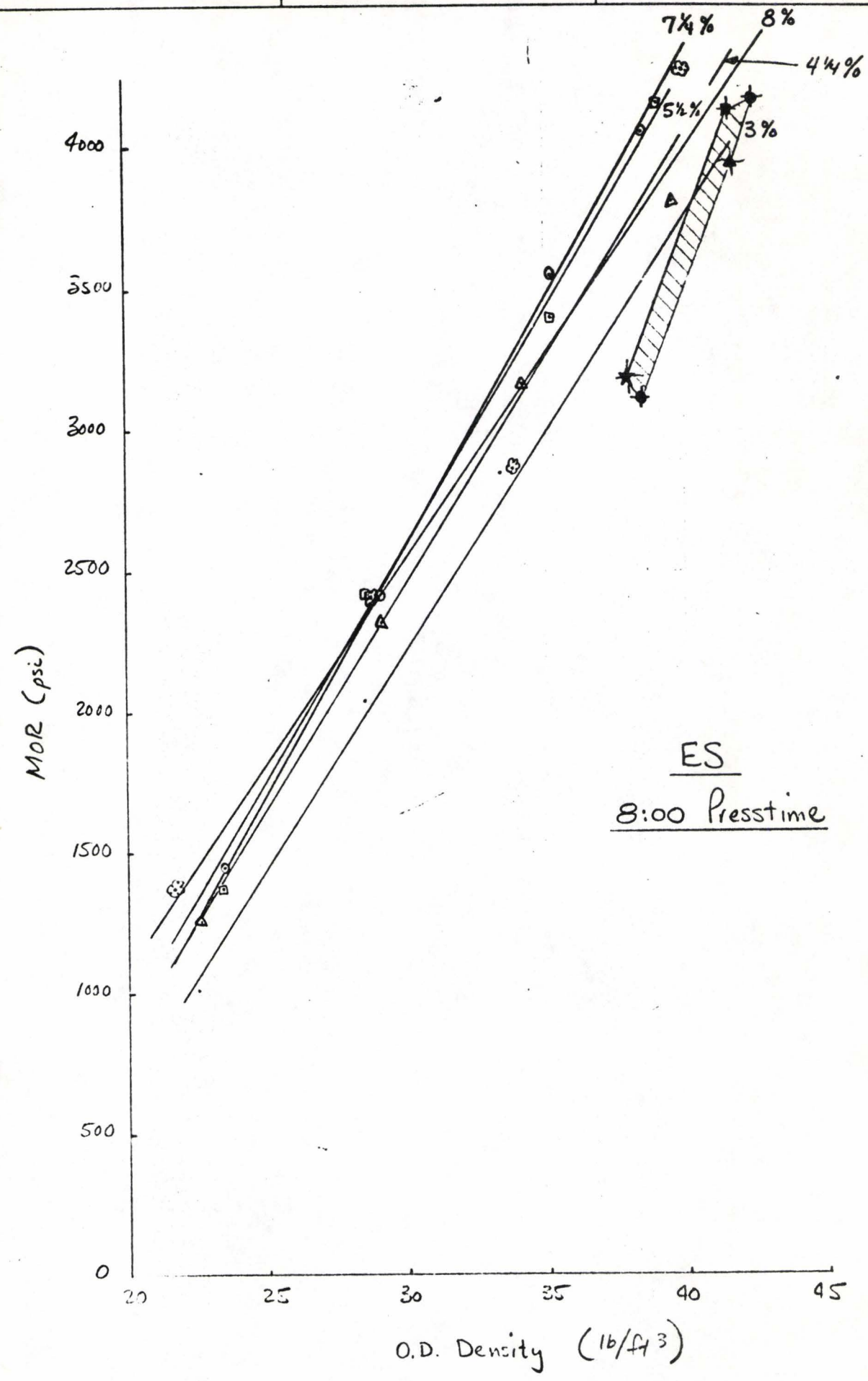

Figure 1. Engelmann Spruce Particleboard MOR (psi) versus Board O.D. Density (lb./ft.^{3})

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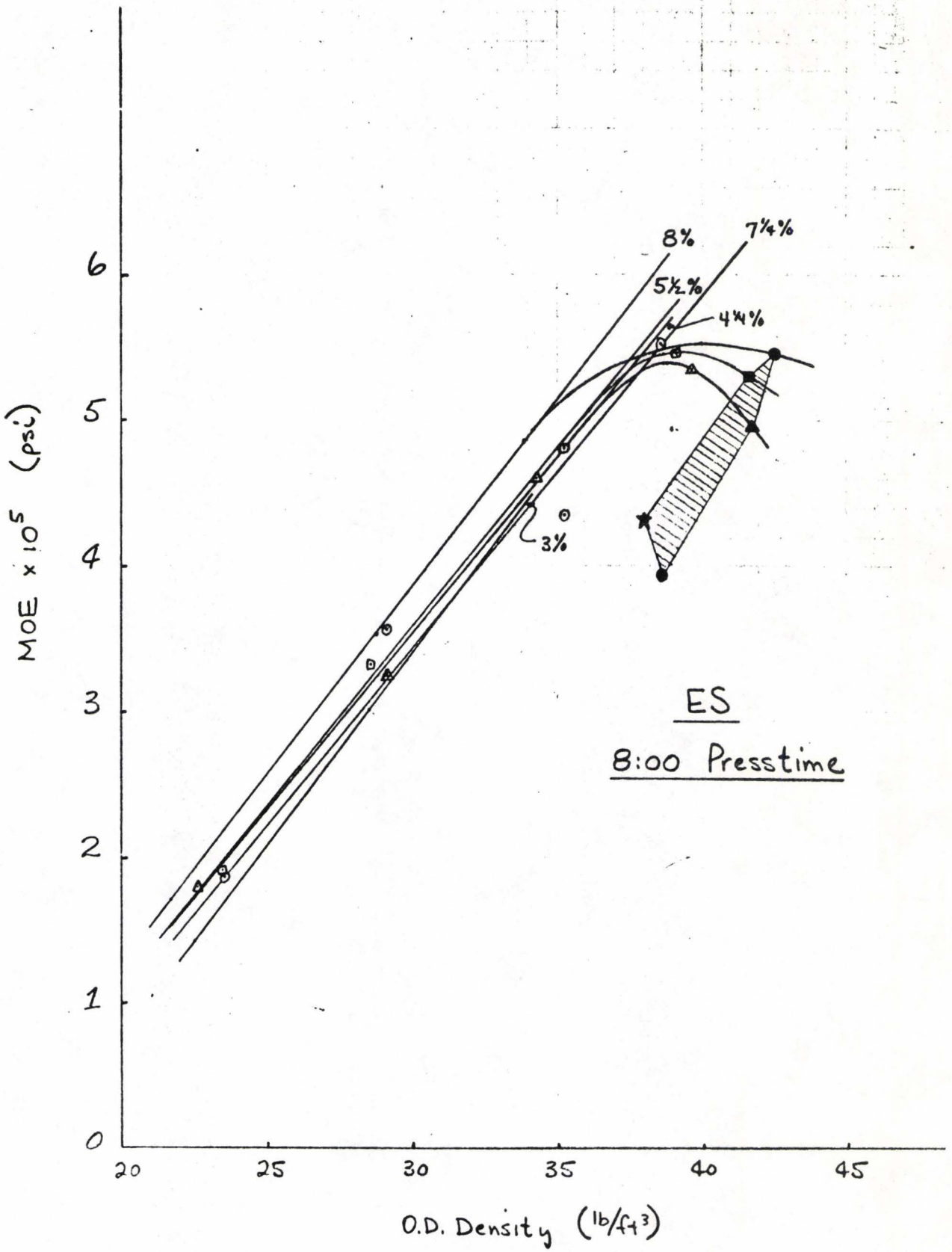

Figure 2. Engelmann Spruce Particleboard MOE (psi) versus Board O.D. Density (lb./ft.^{3})

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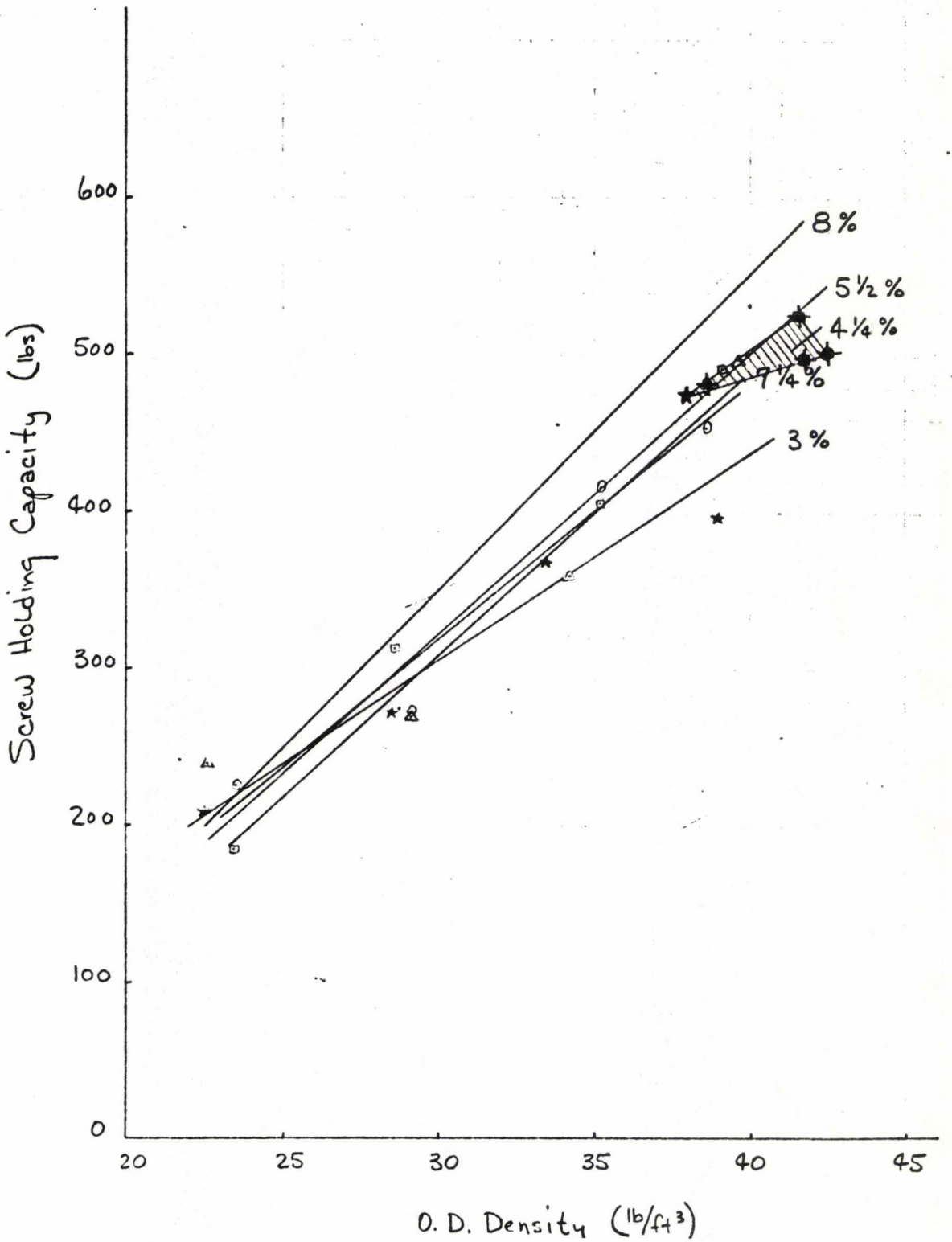

Figure 3. Engelmann Spruce Particleboard Screw Holding Capacity (lbs.) versus Board O.D. Density (lb./ft.^{3})

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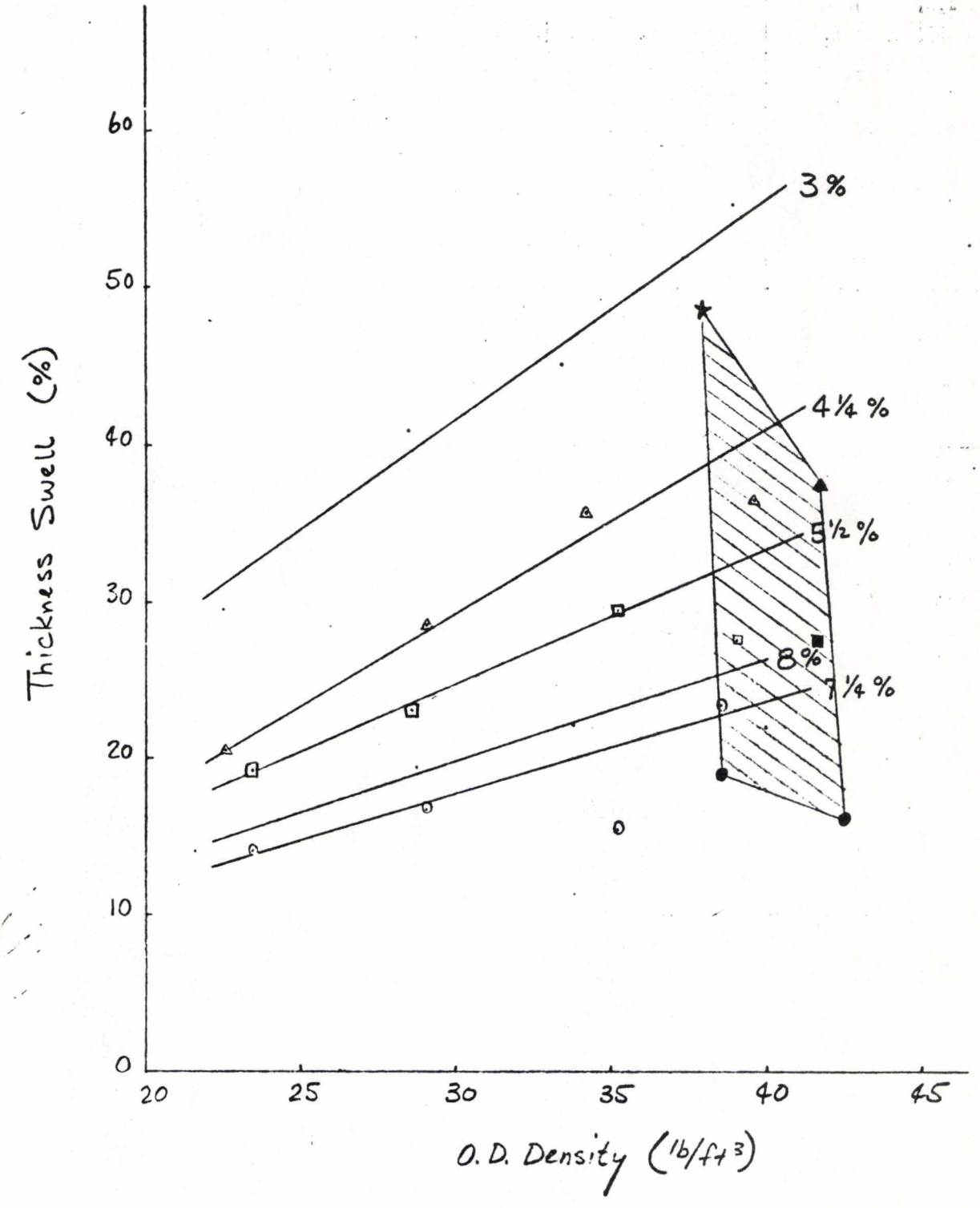

Figure 4. Engelmann Spruce Particleboard Thickness Swell (%) versus Board O.D. Density (lb./ft.^{3})

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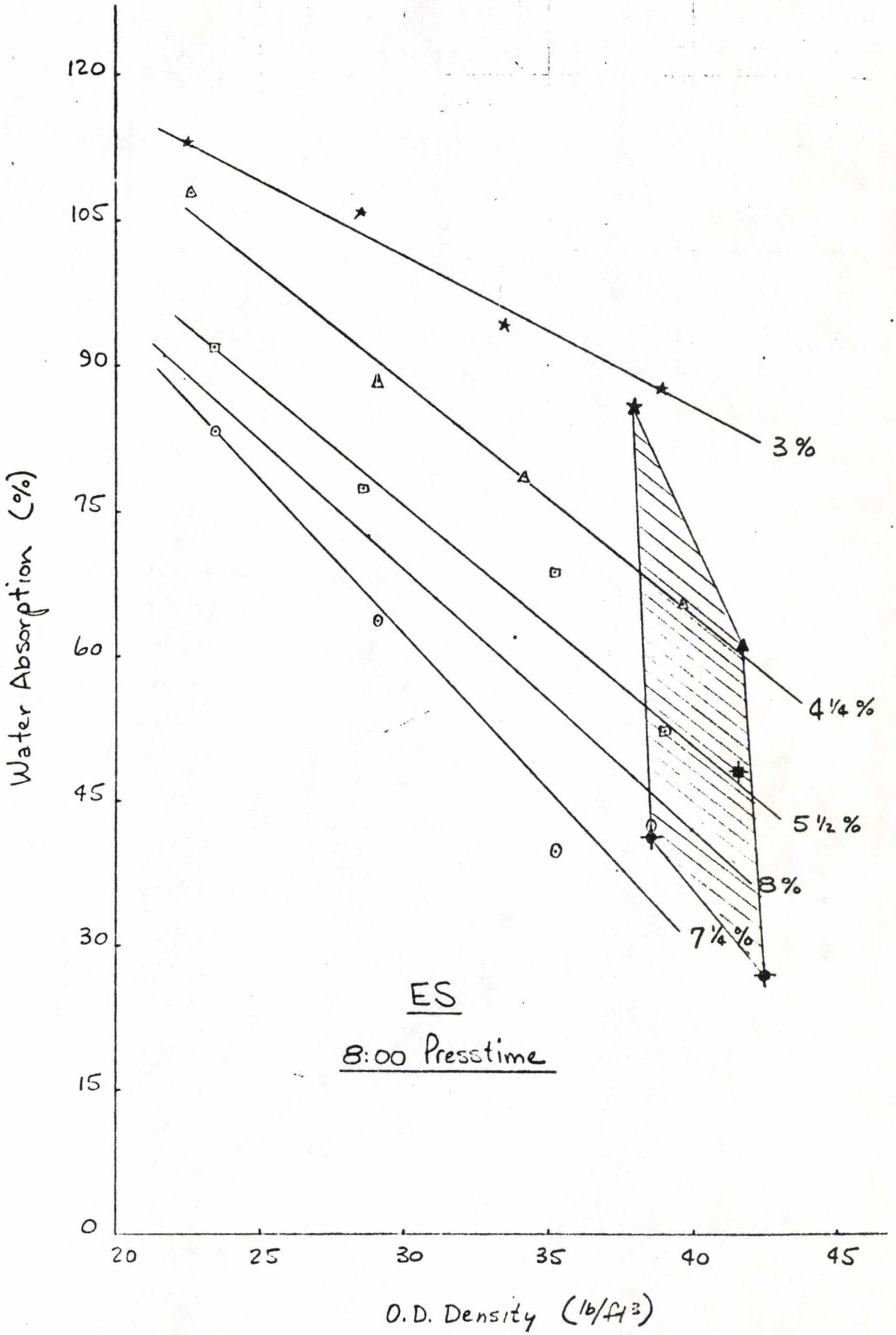

Figure 5. Engelmann Spruce Particleboard Water Absorption (%) versus Board O.D. Density (lb./ft.^{3})

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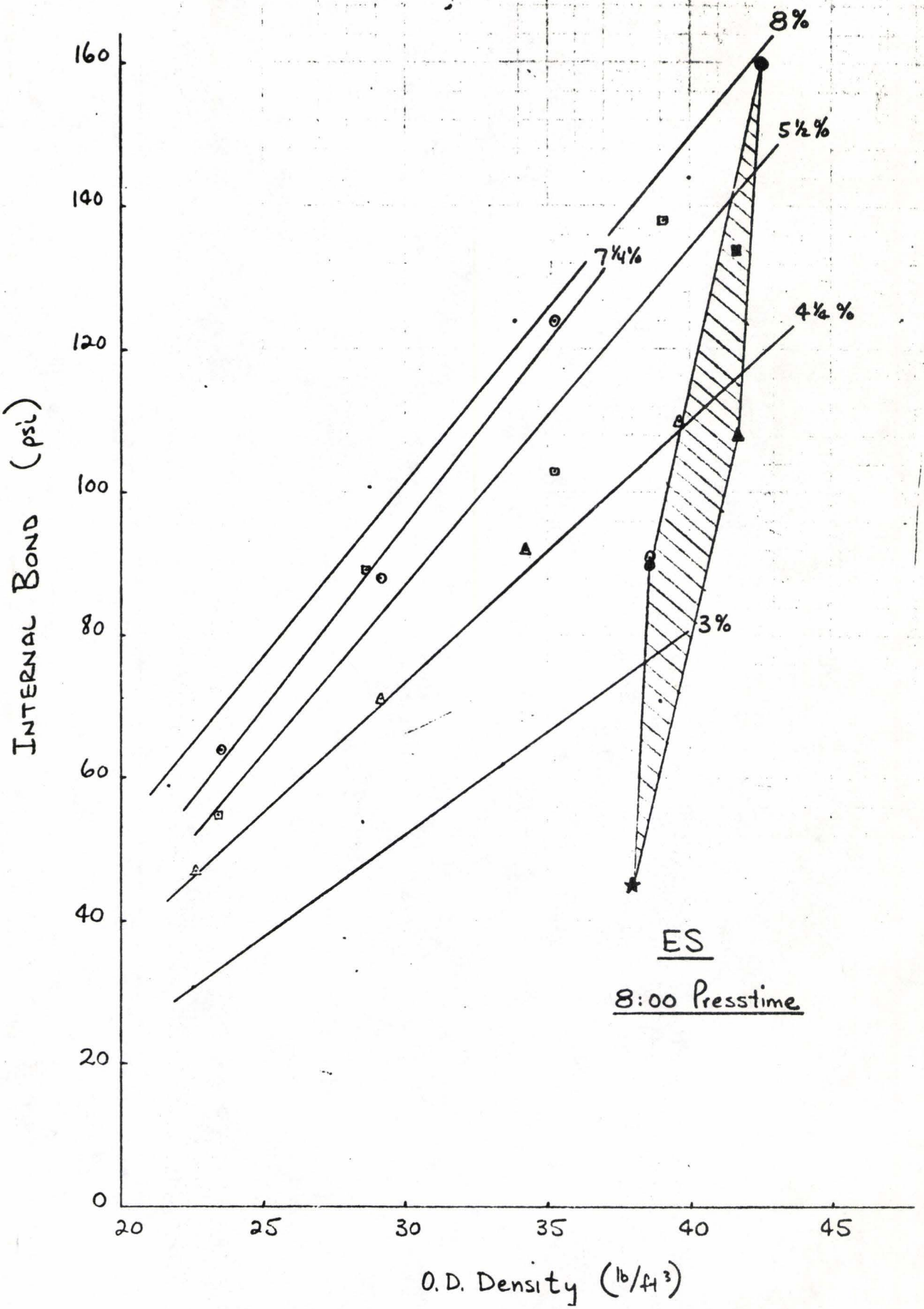

Figure 6. Engelmann Spruce Particleboard Internal Bond (psi) versus Board O.D. Density (lb./ft.^{3})

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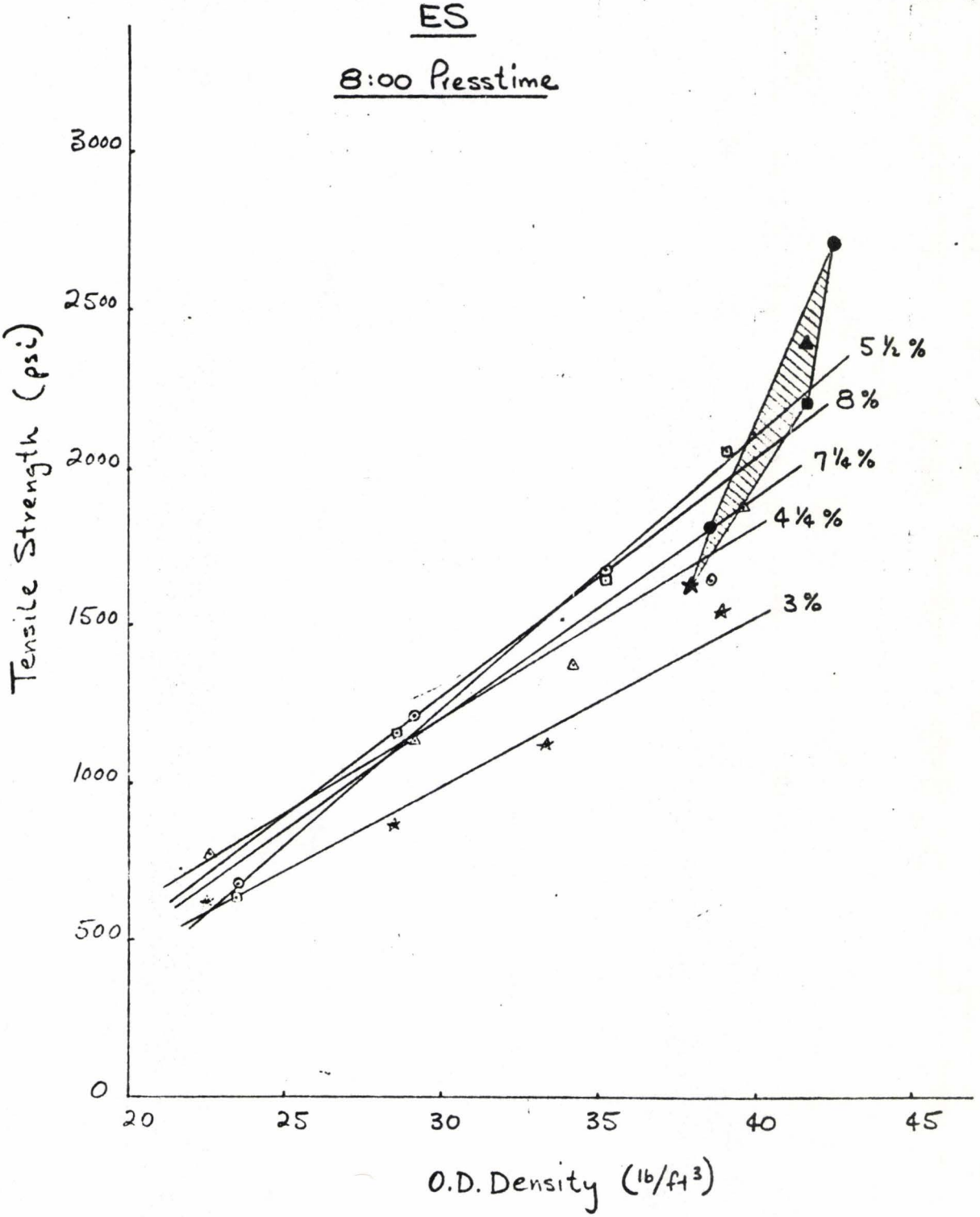

Figure 7. Engelmann Spruce Particleboard Tensile Strength (psi) versus Board O.D. Density (lb./ft.^{3})

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effects included a generally similar response to board density and, at a given density, generally similar MOE, MOR, internal bond strength, and tensile strength and slightly greater water absorption and thickness swell in the case of lodgepole pine.

In a second CSU study, the effect of presstime on the physical properties of lodgepole pine particleboard was examined. The particleboards were manufactured in two different densities, 26.4 and 33.4 lbs./ft.^{3} Presstime, the primary variable of the study, was varied from 3-½ minutes to 20 minutes. Boards pressed for less than 3-½ minutes exhibited severe lack of bond upon removal from the press. The principal conclusion drawn by Bowen (1967a) from this research is that one must consider a number of physical properties and their order of importance to be able to design a press cycle capable of producing the desired end products. In this study, a presstime of 4 minutes gave 75 percent of maximum values for MOR, MOE, tensile strength, and face screw-holding ability. Internal bond required a 7-½ minute press cycle to reach 75 percent maximum value while linear expansion characteristics were still improving at 20 minutes presstime.

Another interesting study by Bowen (1967b) was one done to examine the springback characteristics of lodgepole pine. Fifteen boards of increasing density were pressed by varying the mat weight from 0.7 to 2.4 lb./sq.ft. and pressing under constant conditions of pressure, temperature, resin variables, particle size and panel thickness. Above a board density of 36 lbs./cu.ft. springback occurred, ranging from a 6 percent increase in thickness for a board density of 38.6 lbs./cu.ft. to a 37 percent increase in thickness for a desired board density of 57.9 lbs./cu.ft.

All of the foregoing boards were made from specially processed flakes of uniform length and thickness thus providing comparability under similar press schedules and resin contents. Under such similar conditions no significant differences were established between boards of Engelmann spruce and lodgepole pine except at the lowest resin content.

That the evaluation of a species in terms of particleboard properties is complicated by processing variables is a truism. Self evidence for this truth is provided by Mueller (1959) in an evaluation of beetle-killed Engelmann spruce as raw material for particleboard. At approximately the same density -- 28-30 lb./ft.^{3} -- a hammer-milled sliver-type particleboard showed a MOE of 135,900 psi, a MOR of 3300 psi, and internal bond of 70 psi. A board made from .015-in. thick flakes of the same material exhibited an MOE on the order of 450,000 psi, a MOR on the order of 3300 psi, and an internal bond strength of 116 psi. Comparison of these values with those shown in Figures 1, 2 and 6 at the same density lends additional substance to this assertion.

In a recent study of aspen-birch mixtures for particleboard, Stayton et al. (1971) provided data on another of our study species. Boards were made from the individual species as well as from mixtures of aspen and paper birch. All boards were made from specially prepared flakes 0.014-in. thick and 0.5-in. long. Resin contents were 8% in the case of urea resin and 6% in the case of phenolformaldehyde-bonded boards. The average density of urea-bonded boards was 45.3 lb./ft.^{3} Results which compare most favorably with data from Figures 1-7 at this level of density are shown in Table 2.

An unpublished study at the Colorado State University Wood Science Laboratory has yielded a relationship between the critical density of particle-board (that board density above which severe crushing of particles and spring-back occurs) and species specific gravity (based on O.D. weight and volume at 12 percent M.C.). This relationship is presented as Figure 8. An example of the abruptness of the change in springback at the critical density is shown for ponderosa pine in Figure 9. Analysis of this relationship allows one to identify the upper range of board densities possible for a particular species. The higher density woods are capable of being pressed into a higher density board although this probably depends also on processing variables. However, the authors contend that even though higher density species are capable of producing higher density particleboards, the range of boards possible from low to high density is greater for a lower density species such

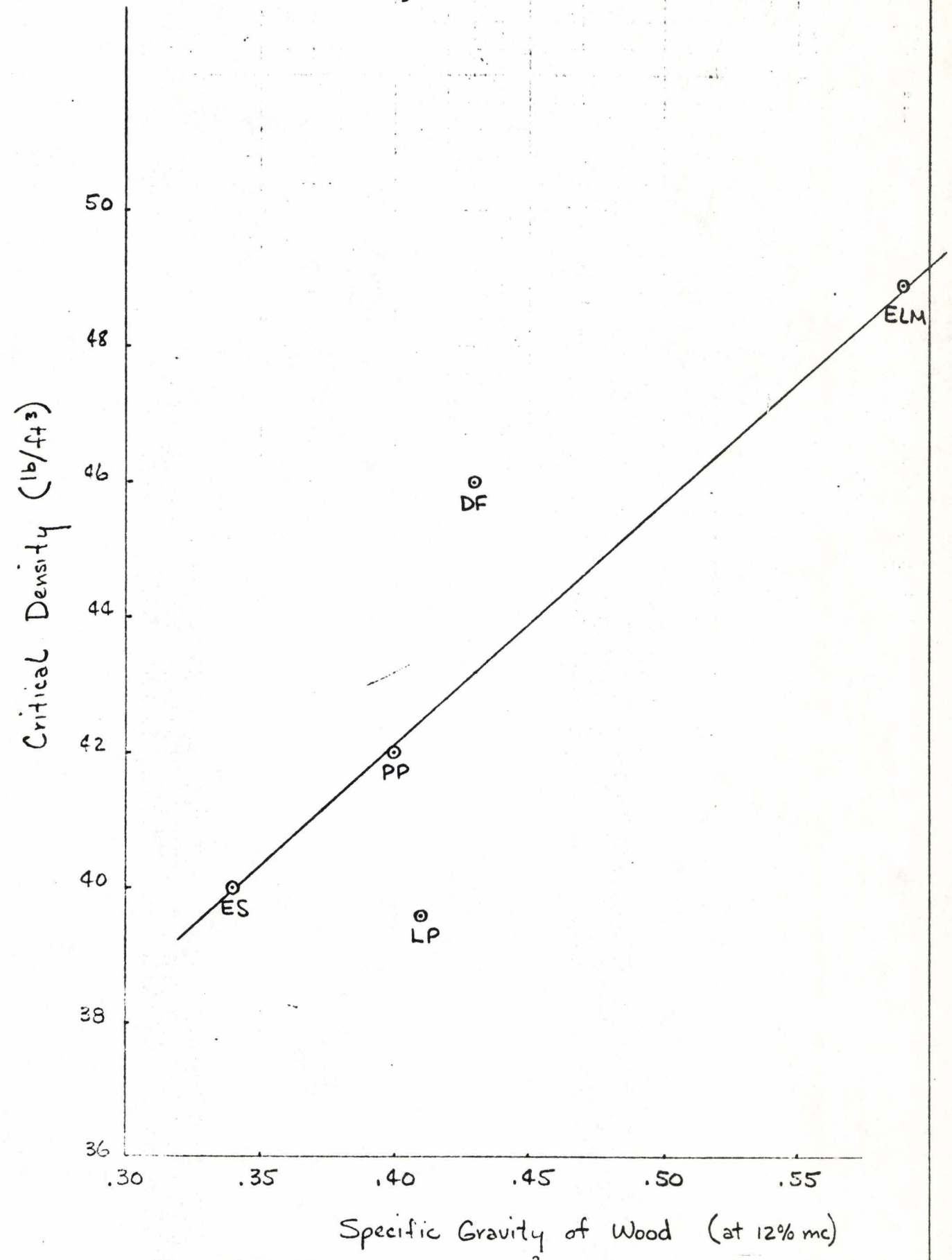

Figure 8. Critical Density (lb.ft.^{3}) of Selected Particleboards versus Specific Gravity of the Wood (at 12% M.C.)

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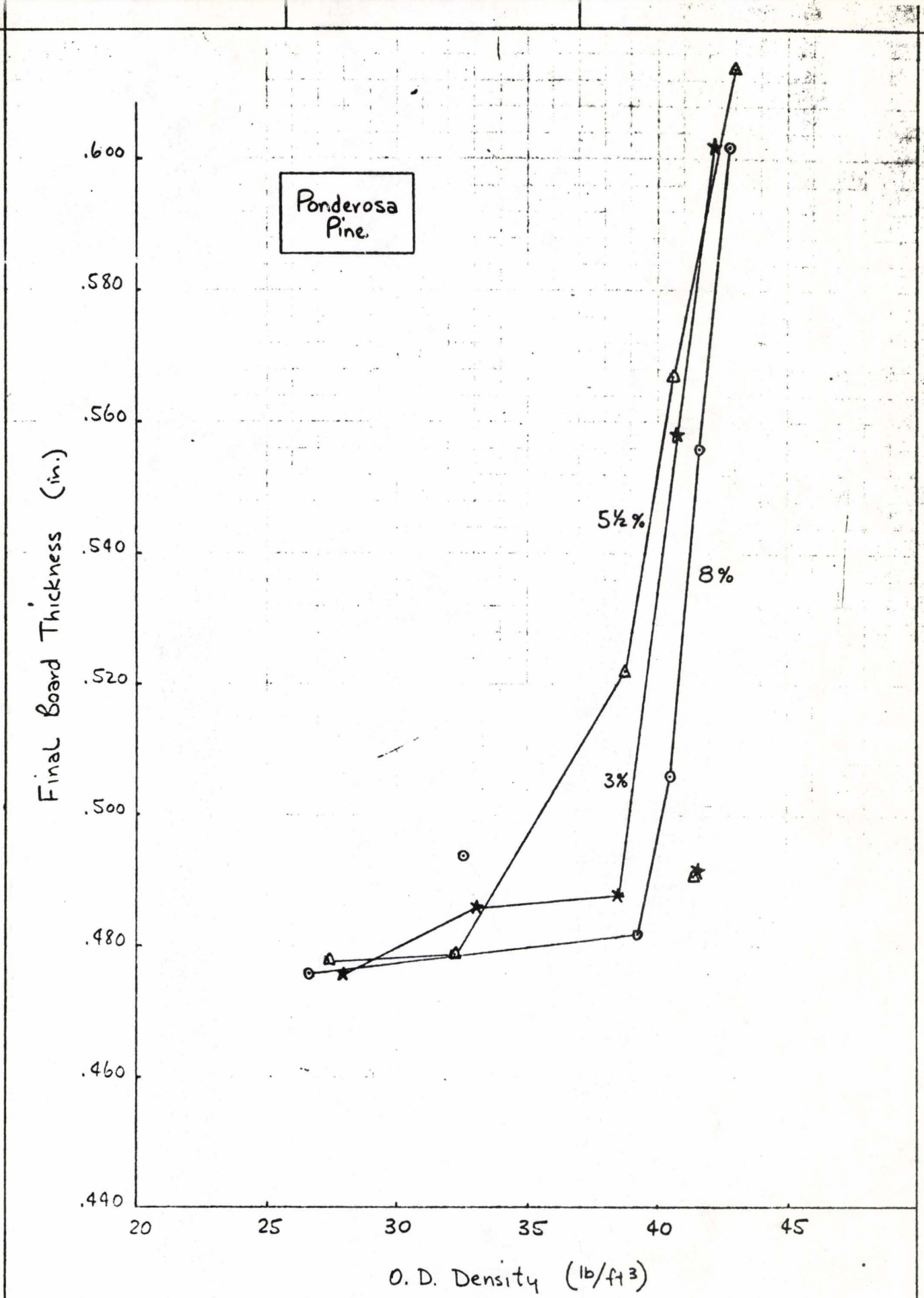

Figure 9. Relationship Between Springback and Particleboard Density for Ponderosa Pine

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Table 2. -- Strength and Dimensional Stability of Particleboard from Different Mix-ratios of Aspen to Paper Birch[1]

Adhesive	Proportion of aspen to birch	Modulus of rupture (psi)	Modulus of elasticity (psi)	Internal bond (psi)	Linear swell 50% to 90% relative humidity (percent)	Thickness swell 50% to 90% relative humidity		Vacuum-Pressure-Soak (VPS)	
						Total swell (percent)	Residual swell (percent)	Total thickness swell (soaked condition)[2] (percent)	Residual thickness swell[3] (percent)
Urea	All Birch	5,100	721,000	172	0.32	22.6	14.2		
	1:2	5,320	786,000	154	.24	18.4	10.5		
	2:1	6,120	858,000	168	.19	16.7	9.5		
	All aspen	6,340	900,000	197	.13	12.6	6.2		
	$SE_{\bar{Y}}$[4]	280	16,000	20	.02	2.2	1.7		
Phenol	All birch	5,510	781,000	217	.19	16.6	7.1	20.1	8.7
	1:2	5,620	835,000	192	.17	15.5	6.1	20.1	9.2
	2:1	6,170	876,000	175	.13	13.9	5.4	19.0	8.6
	All aspen	6,840	963,000	172	.11	12.1	4.0	16.8	6.4
	$SE_{\bar{Y}}$	180	3,000	14	.01	0.7	0.6	0.9	1.0

[1]The urea boards were adjusted to 45.3 and phenol boards to 46.1 lb. per cu. ft. density.

[2]Based on the original thickness at equilibrium with 50% relative humidity.

[3]The percent swelling remaining after the soaked samples were ovendried and equilibrated back to 50% relative humidity.

[4]Standard error of adjusted means.

(Stayton et al., 1971)

as Engelmann spruce (Air-dry volume SG = .35) (Bendtsen et al., 1970), lodgepole pine (SG = .41)(Wood Handbook, 1955), ponderosa pine (SG = .40) (Wood Handbook, 1955), or aspen (SG = .38) (Wood Handbook, 1955). It seems logical to assume that a lower density raw material can be used in making a lower density board and therefore a wider range of technical properties is made possible. More specific information is needed here than seems to be available in the literature.

Comparative Technical Properties Among Particleboards Made from the Study Species

Direct comparisons are possible only between Engelmann spruce and lodgepole pine for reasons explained previously. Based on the testing of several hundred boards made under comparable conditions, it was concluded that, at normal levels of resin content, these two species produce boards that are equivalent in quality, and whose properties are substantially in excess of the requirements for Type 1 particleboard specified in Commercial Standard 236-66. These requirements are shown in this report as Table 1.

From data shown in Table 2 the properties of flakeboard made from aspen are also substantially in excess of the requirements specified in Table 1 which is an excerpt from the Commercial Standard.

Despite efforts to procure comparable laboratory data on ponderosa pine, the only specific results available at this time are from a limited series of tests conducted at CSU on boards made from hammermilled chips and planer shavings. At 8 percent resin content these Type 1 particleboards showed the following:

Density	MOR	MOE	Internal Bond	Water Absorption	Thickness Swell
lb./ft.^{3}	psi	1000 psi	psi	%	%
42.8	3450	360	129	38.9	23.6
41.6	3430	390	114	37.7	36.4
40.4	3480	390	95	37.4	22.9
39.2	2740	340	117	60.1	33.2
32.6	1910	240	90	71.9	29.4
26.7	1440	210	60	80.9	20.3

These data by themselves are of little significance due to the limited testing involved. Nevertheless they lend support to the widely held view that ponderosa pine is an excellent raw material for particleboard -- a statement that can hardly be challenged in the light of the widespread commercial use of this species for particleboard manufacture.

Comparative Properties of Competing Species

Major species used by the particleboard industry are Douglas-fir and southern pine. According to Foster (1967), Douglas-fir usage comprises approximately 22 percent of the total industry tonnage and southern pine approximately 18 percent. Therefore an analysis of the properties of particleboards made from these species is appropriate here. Information prepared by a confidential source comparing physical and mechanical properties of commercially produced boards has been condensed in Table 3 to allow some comparisons to be made between the study species and their major competitors. In the confidential report boards were identified only by year of production and mill origin. To determine the species of the raw material, each mill was cross checked in that year's Reference Data/Buying Guide issue of Wood and Wood Products (1967).

Comparing the values in Table 3 for MOR, MOE, screw-holding ability, water absorption, and internal bond with Figures 1, 2, 3, 5, and 6 provides some interesting results. A 44 lb./cu.ft. commercial board of Douglas-fir or southern pine has a MOR of 2500 to 3000 psi whereas the laboratory-made Engelmann spruce board of 40 lb./cu.ft. density (critical density) lies between 3500-4000 psi. MOE for a 44 lb. Douglas-fir or southern pine board averages approximately 460,000 psi compared to a value of 500,000 - 600,000 psi for a 40 lb./cu.ft. Engelmann spruce board. Screw-holding capacity for Douglas-fir or southern pine would be about 300-360-lbs. and for Engelmann spruce of 40 lb./cu.ft. density about 400-500 lbs. For water absorption the competitive species average about 18.0 percent but a 40 lb./cu.ft. density spruce board manufactured in the laboratory without water repellent shows a value on the order of 30-45 percent. Finally, internal bond for Douglas-fir and southern pine commercial boards of 44 lb./cu.ft. averages about 83 psi whereas for Engelmann spruce internal bond is approximately 100-150 psi.

Table 3. Comparison of Competitive Particleboard Properties by Species.

DOUGLAS-FIR

Density g/cc	Density lb./cu.ft.	Int. Bond psi	MOR psi	MOE psi	Screw Holding Power-face lbs.	24-hr. Water Absorption
.702	43.8	73	2520	464000	333	16.0
.697	43.4	76	2200	380000	271	27.4
.709	44.2	92	2300	399000	292	13.7

SOUTHERN PINE

.699	43.6	94	3220	585000	360	16.0
.776	48.4	244	2310	454000	457	35.2
.777	48.5	174	2450	384000	342	3.2

It appears from this limited comparison that Engelmann spruce laboratory manufactured particleboards compare quite favorably in all properties except water absorption (which presumably could be improved by the inclusion of a water repellent as is customary in commercial production) with a small sampling of commercial Douglas-fir and southern pine boards. The same comparisons hold for lodgepole pine.

In an attempt to more closely correlate the Engelmann spruce data with equivalent resin content percentages in Douglas-fir, data from an article published by Lehmann (1970) were analyzed. A summary of Lehmann's data for 40 lb./cu.ft. boards is presented in Table 4. Comparing the MOE, MOR, internal bond and thickness swell values for Engelmann spruce in Figures 2, 1, 6, and 4, respectively, with Lehmann's data provides the basis for the following observations:

MOE for the Douglas-fir boards with resin contents of 2-8 percent ranges from 336,000-532,000 psi and a similar range for 40 lb./cu.ft. spruce boards is from 500,000-600,000 psi. For MOR the Douglas-fir range is 1463-3213 psi while the spruce data indicate a range of 3000-4000 psi. For internal bond the Douglas-fir range is 18-182 psi and for the spruce data the range is 70-145 psi. And finally, the ranges in thickness swell are 5.5-8.3 percent for Douglas-fir and 15-55 percent for the laboratory-made boards of Engelmann spruce without water repellent. The above comparisons point to the conclusion that the stiffness and strength of Engelmann spruce boards compare favorably with similar density Douglas-fir boards. Internal bond of spruce is approximately equivalent to that of similar density Douglas-fir.

Thermal Conductivity of Particleboards

A physical property rarely considered for particleboards is thermal conductivity. Although applications of particleboard in which thermal conductivity would be of importance are almost non-existent at present, such use may be worthy of consideration by Rocky Mountain producers. Data on the

Table 4. Technical Properties of 40 lb./cu.ft. Douglas-fir Particleboards as Presented by Lehmann (1970).

Spray Pattern	Resin Content (%)	Density (g/cc)	MOE (psi)	MOR (psi)	Internal Bond (psi)	Thickness Swell (%)
Coarse	2	.635	336,000	1463	18	8.3
	4	.642	458,000	2557	78	6.5
	8	.635	517,000	2059	130	5.8
Fine	2	.639	422,000	2137	52	7.3
	4	.642	506,000	2877	106	5.5
	8	.648	532,000	3213	182	5.7

thermal conductivity of particleboard published by Lewis (1967) are presented in Table 5. As can be seen from this table lower density particleboards are much better insulators than high density boards, a possible advantage for the Rocky Mountain study species which are peculiarly adapted to the production of boards of medium to low density.

Conclusions Relative to Technical Properties

From the foregoing discussion, the following conclusions are considered pertinent to this report:

1. Engelmann spruce and lodgepole pine appear to be species capable of manufacture into particleboards ranging in density from approximately 23 lb./cu.ft. to approximately 40 lb./cu.ft. This places them in a position of being in the low or medium density board classifications as delineated by CS 236-66.

   A comparison of CSU-manufactured particleboard properties and the standards of CS 236-66 is presented in the following table as a summary:

	Standard Minimum Value Type 1, Low Density, Class 2	CSU Boards
MOR	1400 psi	1200-3300 psi
MOE	250,000 psi	150,000-500,000 psi
I B	30 psi	50-120 psi

	Type 1, Medium Density, Class 1	CSU Boards
MOR	1600 psi	3300-4200 psi
MOE	250,000 psi	500,000-520,000 psi
I B	70 psi	120-140 psi

	Type 1, Medium Density, Class 2	CSU Boards
MOR	2400 psi	3300-4200 psi
MOE	400,000 psi	500,00-520,000 psi
I B	60 psi	120-140 psi

Table 5. Thermal Conductivity of Particleboard.

Density lb. per cu.ft.	Specific Gravity	Thermal Conductivity BTU, in. per hr., sq.ft., °F
12.5	.2	0.36
25.0	.4	0.52
37.5	.6	0.72
50.0	.8	0.94
62.5	1.0	1.18

(Lewis, 1967)

2. Engelmann spruce (and lodgepole pine) particleboard properties for 40 lb./cu.ft. boards compare favorably in most respects with those of commercial Douglas-fir and southern pine boards at 40-44 lb./cu.ft. density.

3. Table 1 of this report shows the wide range of board densities that the commercial standard encompasses and the property requirements that must be satisfied. As has been demonstrated by the review of studies at the Colorado State University Wood Laboratory, it is possible for particleboard made from Engelmann spruce and lodgepole pine to satisfy these property requirements. Comparable laboratory data are not available for aspen and ponderosa pine but the limited data reported indicate that a favorable potential for particleboard is shared by all of the study species. Since both ponderosa pine and aspen are presently used in the commercial production of particleboard, it is assumed that they also meet the stated property requirements although specific data as to their potential are lacking. To gather more complete technical property information on aspen and ponderosa pine boards will require additional laboratory testing and/or industrial investigation.

4. Testing should be undertaken to determine the upper and lower limits of board density (critical densities) that may be feasible in producing boards from all of the study species as well as from Douglas-fir and southern pine. The effects of processing variables should be considered in any such study.

A Survey of Widely Used Specifications and Model Code Requirements for Particleboard Products Marketed in Rocky Mountain and Midwest Areas

The Uniform Building Code, the Basic Building Code, and the National Building Code are the only model building codes used in the study market area. The Uniform Building Code, which is used in Denver, is the more progressive building code. The National Particleboard Association has worked with the International Conference of Building Officials to include particleboard in the Uniform Building Code. As far as could be determined the Uniform Building Code is the only model code in the nation that has specifications for particleboard.

The Federal Housing Authority has also written specifications for particleboard. Currently, the FHA is in the process of revising their particleboard specifications. The revisions as they now stand are included in this report. These revisions, however, are subject to approval by several more authorities within the FHA before they can be accepted and published.

The National Particleboard Association has several specifications concerning particleboard for use as floor underlayment and as decking for factory-built homes. These specifications have been requested, but not received.

Information pertaining to specifications and model code requirements for particleboard follows:

Floor Underlayment

FHA Interim Revision No. 52, June, 1971.
705-9.1. Particleboard floor underlayment shall comply with C.S. 236-66 type 1-B-1 and, in addition shall exhibit a maximum thickness swelling of 0.063 inch when immersed in water for 24 hours in accordance with ASTM D-1037.

705-9.2. Particleboard floor underlayment shall be grademarked as to its compliance with 705-9.1. NPA or TECO grademarks shall be accepted as evidence that the underlayment complies with these standards.

Combination Subfloor/Underlayment Particleboard for Factory Built Modular Housing Units

FHA Use of Materials Bulletin No. UM 57, August 1970.

Particleboard acceptable for use within the scope of this bulletin shall comply with all the requirements of type 2-B-2 of C.S. 236-66 except that the linear expansion value may be 0.35 percent rather than 0.25 percent.

The "Hardness" provision for B density particleboard indicated in paragraph 3.4.3. of C.S. 236-66 is required.

In addition to the requirements of C.S. 236-66, particleboard shall also meet all provisions of the National Particleboard Association Standard NPA 2-70, "Standard for Particleboard Decking for Factory Built Housing."

Exterior Use

FHA Use of Materials Bulletin No. UM 32, June 1961.

This bulletin is being revised. The following revision is to be made: Particleboard used for exterior use shall conform with C.S. 236-66 type 2-B-1.

Uniform Building Code (1970 edition), Section 2517-5.

Where particleboard is used for covering the exterior of outside walls, it shall be of exterior type 2-B-1 conforming to C.S. 236-66, not less than 5/8-inch thick, and not less than 3/4-inch thick when applied directly to framing spaced 24 inches on center.

Structural Grade Particleboard

FHA Use of Materials Bulletin (Structural Sheathing).

Structural grade particleboard is to be covered under a separate Use of Materials Bulletin (Structural Sheathing) and shall meet the requirements of type 2-B-2 as described in C.S. 236-66 and racking test requirements of FHA Technical Circular No. 12.

Bracing

Uniform Building Code (1970 edition), Section 2518-5-F.

All exterior walls and main cross stud partitions shall be effectively and thoroughly braced at each end, or as near thereto as possible, and at least every 25 feet of length by one of the following methods, which includes particleboard.

Particleboard to be used shall be type 2-B-1 sheathing panels not less than 3/8-inch thick on studs spaced not more than 16 inches on center conforming to C.S. 236-66.

Rocky Mountain and Midwest Areas That Appear To Be The Best Markets for Rocky Mountain Produced Particleboard

The North Central Region which includes: Indiana, Ohio, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North and South Dakota, Nebraska and Kansas, as used by the Bureau of the Census, plus Colorado and Wyoming are considered to be the prime market areas for Rocky Mountain particleboard, based on the difference between volumes of production and consumption and the transportation advantage that Rocky Mountain producers have in this territory.

A comparison of particleboard production and estimated consumption in the North Central Region and Colorado and Wyoming indicated that every Major Trading Area (as defined by Rand McNally) in the proposed market territory, except Milwaukee and Indianapolis, consumes more particleboard than it produces. The percentage of particleboard consumed in each Major Trading Area was estimated by assuming that particleboard is consumed in the same geographic locations as sanded and underlayment plywood, since these plywood products are consumed by the same kind of firms as particleboard; e.g., residential homebuilders, furniture manufacturers, millwork firms, etc. This is only a first approximation in lieu of more accurate data. This procedure was used because area consumption statistics are available for plywood but not for particleboard (Bruce, 1970). Using this procedure it was found that slightly over one third of the entire particleboard deficit in the entire country (consumption less production) is found in the proposed market territory.

The Major Trading Areas in the market territory are:

Trading Area	Annual Production Capacity MM sq.ft.(3/4 in.)	Estimated Consumption MM sq.ft.(3/4 in.)	Surplus or Deficit
Chicago, Ill	0	170.0	-170.0
Cincinnati, Ohio	0	27.5	-27.5
Cleveland, Ohio	0	37.5	-37.5
Columbus, Ohio	0	15.0	-15.0
Denver, Colo	0	30.0	-30.0
Des Moines, Iowa	0	25.0	-25.0
Detroit, Mich	40	90.0	-50.0
Indianapolis, Ind	34	25.0	+9.0
Kansas City, Missouri	0	50.0	-50.0
Milwaukee, Wis	60	42.5	+17.5
Minneapolis, Minn	14	62.5	-48.5
Omaha, Nebraska	0	20.0	-20.0
St. Louis, Missouri	0	35.0	-35.0
Wichita, Kansas	0	12.5	-12.5
TOTAL	148	642.5	

(Bruce, 1970)

The particleboard producers in the market territory are:

Producer	Location	Annual Production Capacity MM sq.ft. 3/4-inch basis
Storrs Wood Products	Evanston, Indiana	24
Swain Industries, Inc.	Seymour, Indiana	10
U.S. Plywood - Champion	Gaylord, Michigan	40
Rodman Industries	Marinette, Wisconsin	20
Weyerhaeuser	Marshfield, Wisconsin	40
Cladwood Co.	Virginia, Minnesota	14
TOTAL		148

(Staepelaere, 1971)

A confidential industry report bearing a 1968 date shows that the North Central Region has the greatest growth potential among all the regions in the United States. It is estimated that demand will increase from 194MM sq. ft. in 1965 to 514MM sq. ft. in 1975. The North East, which is the next most likely market, will grow from approximately 139MM sq. ft. in 1965 to 351MM sq. ft. in 1975 -- not quite as active as the North Central Region. These figures are considerably less than the estimates supplied by Bruce, but are considered to be more accurate than Bruce's because they are based on actual particleboard consumption.

The biggest increase from 1965-1975 in the North Central region will be in furniture (an increase of 122.4MM sq. ft.). Closely following furniture is the construction market with an increase of 118MM sq. ft. Mobile home manufacturers will increase their use of particleboard by 60.1MM sq. ft. (Confidential Industry Report, 1968).

In a market analysis of the use of particleboard in Minnesota, North Dakota, South Dakota, Nebraska, Iowa, and Wisconsin (use of particleboard in the large construction and remodeling markets was excluded from this study), it was found that none of the particleboard purchased in 1963 by the respondents of the survey was manufactured in the area surveyed. The study showed that at least 91% was produced on the West Coast and shipped into the area surveyed. Undoubtedly a large percentage of the volume listed as unknown origin also is from the West Coast. Of the 91%, California mills supplied 69% and Oregon mills 22%. Arkansas, Virginia, and North Carolina mills produced small quantities used by the respondents (Duncan, 1964). Of significance is the additional fact that most particleboard coming into the North Central Region for industrial use was shipped a long distance, which further strengthens the proposition that the Rocky Mountain Region may be in an advantageous position as a supplier to the North Central States.

It should be remembered that although the proposed market territory is considered to be the North Central States, market areas are not limited by political boundaries and this area must remain flexible. Many marketing studies for a product like particleboard have been based on regional distribution when, in reality, the true pattern of sales is more national in scope. This is necessary because of advertising programs and the central purchasing practice of industrial users. One should not, too early in the study, limit himself to a definite area, but rather continue to consider other areas that may be possible markets.

The Structure, Conduct, and Performance of Existing and Currently Planned Particleboard Markets In the Defined Areas

The two main sellers of particleboard are wholesalers and retailers. In general most retailers purchase particleboard from the wholesaler who supplies the majority of the other forest products carried. Very few retail lumber dealers purchase particleboard as an independent item (Mount, 1967). In the Southwest, only 24 percent of the retailers bought particleboard directly from the manufacturer while the remaining 76 percent bought from wholesalers (Gray, 1970).

Retailers sell most of their particleboard to building contractors, but over a quarter of their supply is sold to individual consumers (Gray, 1970). The National Particleboard Association reports that 27 percent of particleboard sales by retailers go to handymen (Crow's, 1968). Mount (1967) reports that building materials purchased for single family construction are bought directly from a retail lumber dealer. The retailer provided a bulk breaking service in which the materials for an individual dwelling unit were delivered to the site of construction. The contractor demanded no specifications of the retail lumber dealer with regard to brand name of the particleboard, specifying only the size of panel desired. The contractor assumed the existence of a guarantee with the particleboard transaction and did not use the presence or absence

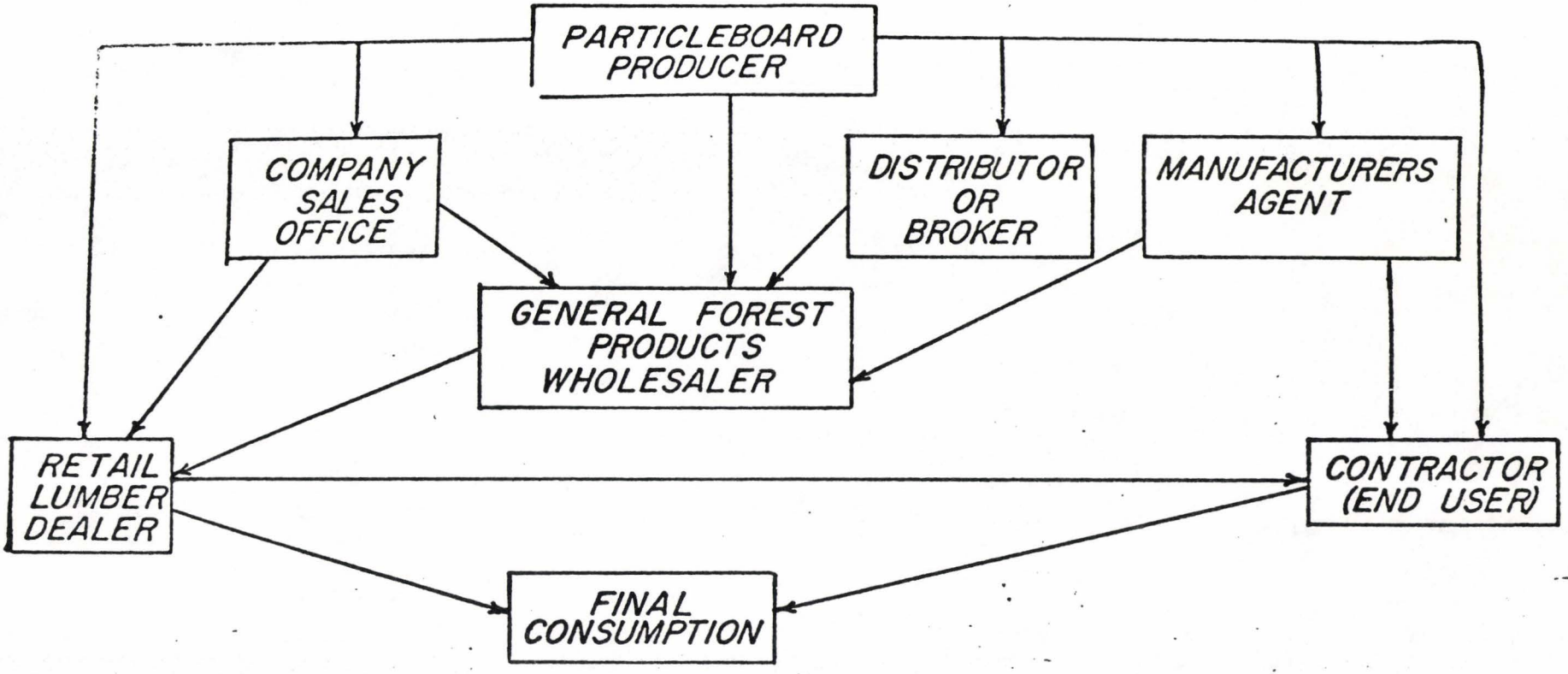
of a guarantee as a limiting factor in the purchase. The purchase decision was made by the prime contractor in almost every case. The retail lumber dealer made the decision as to brand, size, and quality of particleboard to stock (Crow's, 1964).

In general it can be said that of the half billion feet of production in 1964 it appears that about a third, or over 165 million sq. ft. was distributed through retail building material dealers. Most of this was floor underlayment grade, but there was also a growing over-the-counter demand from small commercial users and do-it-yourself remodelers. This latter demand is for unfinished boards used for such varied purposes as wardrobe doors, shelving, and cabinet work (Crow's, 1964).

Wholesalers generally buy particleboard direct from the manufacturer. Over half of the particleboard sold by wholesalers in the Southwest market area went to retail lumber dealers. Building contractors were second in importance to lumber firms, followed by industrial firms (Gray, 1970).

Mount (1967) found essentially the same situation in his study of the Denver market. In particular, those building contractors who were primarily in the multi-family residence business, dealt with wholesalers. Others dealing directly with wholesalers were cabinet makers and camper manufacturers. Plastic laminating, store display, and fixture manufacturers purchased their material direct from the manufacturer through company sales offices.

Mount's study as do other studies, found that brand name and guarantee did not influence the purchase of particleboard. Figure 10 shows a particleboard flow chart for Denver.



PARTICLEBOARD FLOW CHART FOR DENVER

FIGURE 10.

(Mount, 1967)

An Estimation of Volumes Presently Consumed in the Defined Market Territory by Type and End Use

Richard Bruce (1970) in his first approximation of particleboard consumption in the proposed market territory, arrived at the figure of 642·5MM sq. ft. for 1970, based on the assumption that particleboard consumption has the same geographical distribution as plywood consumption. Confidential Industry Report (1968) and Peter Mount (1967) in more detailed studies estimated the consumption figure for the proposed market territory to be 384.2MM sq. ft. for 1970. The Confidential report estimates are the more conservative so these estimates will be used here for particleboard demand in 1965, 1970, and 1975 in the North Central States. Peter Mount's figures will be used for the Colorado area. No figures are available for Wyoming but use in that state is assumed to be minimal.

A word of caution is in order. Published statistics on the various end-uses of particleboard are few and far between -- a USDA Forest Service Report on industrial uses in 1960, another Forest Service Report covering construction uses in 1962, parts of the 1963 Census of Manufacturing Industries, and the annual statistics for total particleboard production published by the U.S. Department of Commerce in their Current Industrial Report series are the major sources of information. It will be appreciated that any analysis, and especially any forecasts, based on such limited data must necessarily be open to substantial error. It is felt, however, that the estimates given for 1965, at least, are reasonable (Confidential Industry Report, 1968). Table 6 gives the estimated demand for particleboard by end-use for the North Central States plus Colorado and Wyoming.

Information on the type of particleboard demanded is rather difficult to determine, although some generalizations and a few specific details can be given. Particleboard is manufactured in both 4- and 5-foot widths, although for industrial sales much is cut to size for the purchaser. In construction.

Table 6. Estimated Demand for Particleboard
North Central United States and Colorado and Wyoming
Million Square Feet, 3/4-inch basis

END USE	1965	1970	1975
CONSTRUCTION			
1 & 2 Family Houses	11.8	15.0	13.8
Prefabricated Houses	22.2	34.1	52.1
Multi-Family (Apartments)	6.2	8.8	10.5
Nonresidential Construction	9.2	15.3	26.0
Repairs and Remodeling	29.5	65.2	94.5
SUBTOTAL CONSTRUCTION	78.9	138.4	196.9
FURNITURE & FIXTURES			
Household Furniture (Wood)	38.4	82.7	106.2
Household Furniture (Metal)	21.0	27.2	30.9
Office Furniture (Wood)	2.5	5.7	10.4
Public Bld. Furniture	10.0	16.0	22.0
Partitions & Furniture	14.7	27.3	36.8
Misc. Furniture etc.	2.1	2.8	3.2
SUBTOTAL FURNITURE	89.5	163.2	211.9
INDUSTRIAL USES			
Mobile Homes	15.0	36.0	75.1
Misc. Industrial Uses	10.3	19.6	30.5
SUBTOTAL INDUSTRIAL USES	114.8	218.8	317.5
NORTH CENTRAL U.S.	193.7	357.2	514.4
DENVER CONSUMPTION	25.0	27.0	47.0
TOTAL CONSUMPTION	218.7	384.2	561.4

(Confidential Industry Report, 1968; and Mount, 1967)

the common size panel is 4 by 8 feet, as for other panel materials. Extruded particleboards are always used as corestock; mat-formed ones are used both as corestock and as panel stock where the only thing added to the surface is finish. Most of the particleboard sold is mat-formed and is of medium density.

For the majority of uses where exposures are interior or equivalent (furniture, cabinetwork, interior doors, and most underlayment), urea-formaldehyde resins are used. Boards with that kind of bond are classed as Type 1 in specifications. Where greater resistance to heat, moisture, or a combination of heat and moisture is required, Type 2 boards generally bonded with phenolic resin should be specified.

In the construction market, the most popular thickness of board for underlayment is 5/8 inch, which constitutes 2/3 of the entire underlayment produced in 1970; 3/8 inch, used mainly in remodeling, is next, accounting for 1/6 of underlayment production (U. S. Dept. of Commerce, 1970). Most of the particleboard used by the construction industry is for underlayment and the most common dimension is 4 by 8 feet. Separate use specifications cover particleboard floor underlayment. In addition, all manufacturers of particleboard floor underlayment provide individual application instructions and guarantees because of the importance of proper application and the interaction effects of joints, sub-floor, underlayment, adhesives, and finish flooring.

In the industrial use market, more specific data are available from the study done by the Great Northern Railway. From Table 7 it may be seen that 60 percent of the board purchased by industrial users in the North Central Region was without an overlay, 33 percent had a plastic overlay, 2 percent had a wood veneer surface, and 5 percent was unknown.

Table 7. Volume of Particleboard Used in 1963 in North Central Region (1000 sq. ft., 3/4 inch basis) by End Product Use and Type of Overlay When Purchased.

State and Type of Overlay	Furniture	Counter tops	Under-layment	Table tops	Cabinets	Display and store fixtures	Door cores and doors	Millwork	Other 1/	Unknown	Total
Minnesota											
Plastic	0	695	0	360	10	57	0	30	0	0	1,152
Veneer	0	0	0	0	27	12	1	48	0	0	88
None	172	10	70	3	262	46	0	0	112	0	675
Unknown	0	0	0	0	10	0	0	30	0	176	216
Total	172	705	70	363	309	115	1	108	112	176	2,131
Wisconsin											
Plastic	54	21	3	118	13	28	3	0	3	0	243
Veneer	0	0	0	0	3	2	0	0	0	0	5
None	1,728	0	24	0	15	1	0	0	956	0	2,724
Unknown	0	0	0	0	0	0	0	0	5	0	5
Total	1,782	21	27	118	31	31	3	0	964	0	2,977
Iowa											
Plastic	279	277	0	115	2	0	0	3	36	0	712
Veneer	0	0	0	0	34	0	2	0	0	0	36
None	0	273	11	0	1	0	213	0	0	0	498
Unknown	0	5	0	0	0	0	0	0	0	4	9
Total	279	555	11	115	37	0	215	3	36	4	1,255
North Dakota											
Plastic	0	0	0	0	0	0	0	0	0	0	0
Veneer	0	0	0	0	13	0	5	0	0	0	18
None	0	5	10	0	2	0	0	0	0	0	17
Unknown	0	0	0	0	0	0	0	0	0	3	3
Total	0	5	10	0	15	0	5	0	0	3	38
South Dakota											
Plastic	0	13	5	0	3	0	0	0	0	0	21
Veneer	0	0	0	0	0	0	0	0	0	0	0
None	10	5	135	0	51	0	0	0	0	0	201
Unknown	0	3	0	0	0	0	0	0	0	0	3
Total	10	21	140	0	54	0	0	0	0	0	225
Nebraska											
Plastic	0	0	0	0	0	0	0	0	500	0	500
Veneer	0	0	0	0	1	0	0	0	0	0	1
None	11	7	472	0	60	0	39	0	0	0	589
Unknown	0	0	0	0	0	145	0	0	0	2	147
Total	11	7	472	0	61	145	39	0	500	2	1,237
Total	2,254	1,314	730	596	507	291	263	111	1,612	185	7,863

1/ Includes sporting goods, toys, novelties, crating spacers and other products.

(Duncan, 1964)

The most frequently used thicknesses were 3/4 inch and 5/8 inch, as shown in Table 8. Thicknesses ranged from 1/4 inch to 1 3/8 inches, but relatively insignificant volumes of board under 5/8 inch and above 1 1/8 inches were used.

The preferred dimension of particleboard for furniture manufacture is 4 by 8 feet, although it was reported in 1957 that panel sizes of 5 feet by 11 1/2 feet and 5 3/4 by 11 1/2 feet were becoming popular (Van Hullen, 1957). Particleboard has taken a firm hold in the mobile home industry because panels are being made to fit trailers instead of the standard 4-by 8-foot plywood size.

An Evaluation of Price and Other Competitive Factors Relative To Alternative Materials

To understand how particleboard was able to gain rapid market acceptance and achieve a growth rate exceeding other building materials, it is necessary to understand the advantages and disadvantages of the product. The particular characteristics, which are the advantages of the product, that have contributed to market acceptance of particleboard are given in the following tabulations (Mount, 1967).

Advantages of Particleboard

Dimensional Stability	Uniform Density
Good Screw Holding Capacity	Freedom From Warp
Reasonable Flexibility	Good Compressive Strength
Low Cost Material	Good Shear Strength
Ability to Be Molded into Shape	Good Gluing Properties
Made From Low Grade Material	Utilize Any Species of Wood
No Hidden Defects In Board	Production Process Highly Automated
	Smooth Surface

These advantages have created a place in the building materials market for particleboard. The products which have been replaced by particleboard are plywood, hardboard, solid lumber, and insulation board.

Table 8. Quantity of Particleboard Used by 125 Firms in 1963 By Thickness in North Central Region.

Thickness (Inches)	Quantity 1000 sq. ft. (3/4-inch Basis)	Percent of Total
1/4	3	*
3/8	210	2.7
1/2	87	1.1
5/8	1,629	20.7
3/4	4,839	61.6
7/8	8	.1
1	672	8.5
1 1/8	382	4.9
1 1/4	2	*
1 3/8	31	.4
Total	7,863	100.0

* Less than 0.1 Percent

(Duncan, 1964)

The characteristics which are preventing greater acceptance of particleboard as building material are the disadvantages of the product. The following tabulation lists the disadvantages of particleboard (Mount, 1967).

Disadvantages of Particleboard

Variable Structural Strength	Lack of Standardized Grading System
High Cost For Exterior Panel	Need For Uniformity Between Firms
Low Utilization of Resins	Urea Formaldehyde Residual Odors
Long Pressing Cycles	Unorganized Market Structure
Production Defects	Poor Edge Characteristics

Plywood probably has suffered most from the increased utilization of particleboard. Particleboard is being increasingly used as floor underlayment for both residential construction and the trailer manufacturing industry. As floor underlayment, particleboard provides (1) the leveling, (2) the thickness of construction required to bring the final floor to elevation, and (3) the indentation resistance and smooth surface necessary as the base for resilient finish floors of linoleum, rubber, vinyl, and vinyl asbestos tile and sheet material; all at a low cost.

The 1968 FHA decision including provisions for carpeting in the mortgage package for single family homes has been a major factor in the expansion of the particleboard underlayment market (Crow's, 1968).

Although plywood may be losing ground in some areas, it still has a number of advantages over particleboard. Some of these are listed below (Smetana, 1956).

Advantages of Plywood

Superior strength versus weight ratio
Ease of workability - in sawing, machining, gluing, nailing,and screwing - without danger of edge splitting
Compatibility with a wide variety of finishes
Broad assortment of standard thickness and sizes
Availability of special large sizes
Savings in time and labor in its use and installation
Aesthetic value in the warm beauty of genuine wood
Grain and texture in a form convenient to use
An exterior glue bond impervious to moisture
Savings in redecorating and maintenance costs
Availability on a nationwide basis

A price comparison between plywood and particleboard is quite difficult because in many cases particleboard is not a substitute for plywood and, even when it is a substitute, the wide variety of thicknesses and types makes a comparison most difficult.

The Department of Commerce, Bureau of Domestic Commerce, keeps no information on particleboard prices because of several unusual technical problems associated with reducing the sample data to product prices. However, one private source, the 1970 Yearbook published by Random Lengths, contains price transactions and price trends for 3/8- and 5/8-inch thick particleboard underlayment grade. Also included are price trends and other data on softwood plywood, lumber, veneer and particleboard. Core and industrial grade particleboard prices are not listed in the Yearbook, since these grades are usually sold in custom-cut sizes, and prices are arrived at on a negotiated basis generally not available to the public. The limited amount of information and the difficulty in making accurate price comparisons preclude using the data for this phase of the study.

Some price information is available to demonstrate the obvious advantage particleboard has over plywood. In the particleboard study of the Southwest, the average price paid for interior type (sanded) and exterior type plywood, 5/8-inch basis, by wholesalers and retailers was materially higher than the price paid for particleboard. At $104.00 per thousand square feet wholesale and $113.00 per thousand retail, prices paid for average quality plywood were 65% higher at wholesale and 51% higher at retail than average particleboard prices (Gray, 1970). See Tables 9 and 10.

The U.S. Dept. of Commerce reported that particleboard core stock undersells conventional lumber core by $15.00 per M sq. ft. (U.S. Dept. of Commerce, 1963). Other sources suggest that particleboard core stock undersells conventional lumber by as much as $50.00 per M sq. ft. According to a prominent plywood and particleboard distributor, a 2¢ per square foot ($20 per M sq. ft.) cost differential is extremely important from a competitive standpoint (Weidhaus, 1965).

Table 9. Average Price Paid for 5/8-inch Particleboard by Wholesalers and Retailers in the Southwest, 1966.

Prices Paid by Wholesalers		Prices Paid by Retailers	
Price range $/M sq. ft.	Number of reports	Price range $/M sq. ft.	Number of reports
40-49	6	60-69	178
50-59	12	70-79	272
60-69	35	80-89	234
70-79	46	90-99	66
80-80	17	100-109	37
90 or more	12	110-119	19
		120-129	28
		130-139	19
		140-149	19
		150 or more	9
Total	128		881
Average Price	$63	Average Price	$75

(Gray, 1970a)

Table 10. Average Price Paid for 5/8-inch Interior-Type (Sanded) and Exterior Plywood, by Wholesalers and Retailers in the Southwest, 1966.

Prices Paid by Wholesalers		Prices Paid by Retailers	
Price range $/M sq. ft.	Number of reports	Price range $/M sq. ft.	Number of reports
79 or less	6	70-79	20
80-89	6	80-89	40
90-99	6	90-99	101
100-109	47	100-109	131
110-119	30	110-119	233
120-129	47	120-129	162
130-139	18	130-139	111
		140-149	51
		150-159	51
		160-169	51
		170-179	30
		180-189	20
Total	160		1001
Average Price	$104	Average Price	$113

(Gray, 1970b)

Foreign competition is not yet serious. Currently only 0.3% of the total value of particleboard sold in the U.S. comes from imports (U.S. Dept. of Commerce, 1970). Most of the current imports are from Finland, but Canada remains an imminent threat as an exporter to this country. The possibility of a tariff reduction from the current 12% to 6% would increase imports and make the domestic market more competitive. Not to be overlooked, however, is the possibility of exporting particleboard. This may be a very fertile field to exploit (Bureau of Indian Affairs, 1964).

A fact of considerable significance was discovered in the study done by The Great Northern Railway concerning the use of particleboard as a substitute for other materials. Of the 125 firms surveyed, 46 indicated that they could make from particleboard some product or product parts that are presently made from some other material. In addition, 99 companies not presently using particleboard reported that they were manufacturing items that they thought could be made from particleboard. As knowledge of the product becomes more widespread, over-all consumption could be substantially enlarged (Duncan, 1964).

Transportation Advantages and Disadvantages of Rocky Mountain Producers with Respect to West Coast, Southern and Lake States Producers in Shipping to the Defined Market Territories

Rail is the main mode of transportation used by producers of particleboard, so this comparison is restricted to rail rates. Three production areas with large production figures were chosen from Bruce's (1970) work. These areas are Portland, Oregon; Charlotte, North Carolina; and Birmingham, Alabama. Then two locations were chosen from the Rocky Mountain Region as possible producers. Alamosa in the southern part of the region and Rapid City in the northern portion were chosen as the two most likely sites for a particleboard plant in the eastern and central Rocky Mountain region.

Alamosa was chosen as the most likely area in Colorado because of available volumes of residue and because Alamosa's location is advantageous

from a rail transportation standpoint. When Alamosa's freight rate to Chicago is compared to that of five other Colorado cities (Ft. Collins, Craig, Pueblo, Trinidad, and Montrose), Alamosa has the advantage.

Fifteen major market territories in the North Central and North East Region were selected as final destinations, based on their consumption of particleboard. These areas are: Boston, Mass.; Chicago, Ill.; Columbus, Ohio; Denver, Colo.; Des Moines, Iowa; Detroit, Mich.; Kansas City, Mo.; Milwaukee, Wis., Minneapolis, Minn.; New York, N. Y.; Omaha, Nebr.; Philadelphia, Pa.; St. Louis, Mo.; Washington, D. C.; and Wichita, Kans.

A summary of the specific freight rates presented in the Appendix is shown in Table 11. The conclusions drawn from these rates are the following:

1. The South has a definite freight advantage east of the Mississippi River. The South offers the least expensive freight rates to:

Boston	New York
Chicago	Philadelphia
Columbus	St. Louis
Detroit	Washington, D. C.
Milwaukee	

2. The Rocky Mountain Region has a freight advantage to the marketing territories west of the Mississippi River. In particular, the Region offers the least expensive rates to:

Denver	Minneapolis
Des Moines	Omaha
Kansas City	Wichita

3. In all cases the Rocky Mountain Region has freight advantage over the West Coast as shown in Table 12, although the advantage declines as one goes eastward.

Even in areas where the South has a freight advantage, the low cost of residue in the Rocky Mountains and an unfulfilled potential consumption for particleboard in the market territory should provide a market for Rocky Mountain-produced particleboard.

Table 11. Railroad Freight Rates for Particleboard.

To:	From Alamosa					From Birmingham				
	Minimum Carload	Dollars* per cwt.	Dollars* per Msf	Dollars# per 100M lbs	Dollars# per Msf	Minimum Carload	Dollars* per cwt.	Dollars* per Msf	Dollars# per 100M lbs	Dollars# per Msf
Boston	60M	2.03	53.28	1450	38.06	60M	1.14	29.92	956	25.09
Chicago	50M	1.12	29.40	1120	29.40	60M	.72	18.90	612	16.06
Columbus	60M	1.51	39.63	990	25.99	60M	.63	16.53	526	13.80
Denver	65M	.28	7.35	240	6.30	40M	1.56	40.95	1560	40.95
Des Moines	50M	1.02	26.77	1020	26.77	40M	1.22	32.02	1220	32.02
Detroit	60M	1.53	40.16	1006	26.41	60M	.78	20.47	660	17.32
Kansas City	50M	.85	22.31	850	22.31	40M	1.12	29.40	1120	29.40
Milwaukee	70M	1.30	34.12	1300	34.12	60M	.78	20.47	660	17.32
Minneapolis	50M	1.12	29.40	1120	29.40	40M	1.34	35.17	1340	35.17
New York	60M	1.96	51.45	1392	36.54	60M	.97	25.46	822	21.58
Omaha	50M	.85	22.31	850	22.31	40M	1.28	33.60	1280	33.60
Philadelphia	60M	1.92	50.40	1352	35.49	60M	.90	23.62	908	23.83
St. Louis	50M	1.06	27.82	1060	27.82	60M	.51	13.38	445	11.68
Wash., D. C.	60M	1.85	48.56	1290	33.86	60M	.59	15.48	559	14.67
Wichita	50M	.85	22.31	850	22.31	40M	1.28	33.60	1280	33.60

*Dollars per cwt. and Dollars per M sq. ft. are computed with stated carload limit.

#Dollars per 100M lbs. and Dollars per M sq. ft. are computed with 100,000 lb. carload minimum.

All values are computed on 3/4 inch basis, 42 lb./cu. ft., 2625 lbs. per M sq. ft.

Table 11. Railroad Freight Rates for Particleboard.
Cont.

To:	From Portland					From Rapid City				
	Minimum Carload	Dollars* per cwt.	Dollars* per Msf	Dollars# per 100M lbs	Dollars# per Msf	Minimum Carload	Dollars* per cwt.	Dollars* per Msf	Dollars# per 100M lbs	Dollars# per Msf
Boston	50M	2.18	57.22	2180	57.23	60M	1.84	48.30	1340	35.17
Chicago	38M	1.93	50.66	1930	50.66	50M	1.08	28.35	1080	28.35
Columbus	50M	2.15	56.43	2150	56.44	60M	1.42	37.27	944	24.78
Denver	40M	1.28	33.60	1280	33.60	50M	.62	16.27	620	16.27
Des Moines	38M	1.85	48.56	1850	48.56	50M	.73	19.16	730	19.16
Detroit	50M	2.12	55.65	2120	55.65	60M	1.39	36.48	954	25.04
Kansas City	40M	1.47	38.58	1470	38.59	50M	.86	22.57	860	22.57
Milwaukee	38M	1.93	50.66	1930	50.66	50M	1.06	27.82	1060	27.82
Minneapolis	38M	1.83	48.03	1830	48.04	50M	.73	19.16	730	19.16
New York	50M	2.18	57.22	2180	57.23	60M	1.80	47.25	1308	34.33
Omaha	40M	1.47	38.58	1470	38.59	50M	.67	17.58	670	17.58
Philadelphia	50M	2.18	57.22	2180	57.23	60M	1.75	45.93	1266	33.23
St. Louis	38M	1.87	49.08	1870	49.09	50M	1.14	29.92	1140	29.92
Wash., D. C.	50M	2.18	57.22	2180	57.23	60M	1.69	44.36	1230	32.29
Wichita	40M	1.47	38.58	1470	38.59	50M	.91	23.88	910	23.89

Table 11. Railroad Freight Rates for Particleboard.
Cont.

From Charlotte

To:	Minimum Carload	Dollars* per cwt.	Dollars* per Msf	Dollars# per 100M lbs	Dollars# per Msf
Boston	60M	.84	22.05	724	19.00
Chicago	60M	.84	22.05	724	19.00
Columbus	60M	.67	17.58	508	13.33
Denver	40M	1.94	50.92	1940	50.93
Des Moines	40M	1.43	37.53	1430	37.54
Detroit	60M	.80	21.00	672	17.64
Kansas City	40M	1.41	37.01	1410	37.01
Milwaukee	60M	.92	24.15	784	20.58
Minneapolis	40M	1.55	40.68	1550	40.69
New York	60M	.71	18.63	598	15.69
Omaha	40M	1.55	40.68	1550	40.69
Philadelphia	60M	.64	16.80	532	13.69
St. Louis	60M	.64	16.80	588	15.43
Wash., D. C.	60M	.41	10.76	561	14.72
Wichita	40M	1.55	40.68	1550	40.69

Table 12. Freight Rate Advantage of Alamosa over Portland, Based on 50M lb. Minimum Weight

Destination	Dollars per cwt.	Dollars per Msf
Denver	1.00	26.25
Des Moines	.83	21.79
Chicago	.81	21.26
St. Louis	.81	20.26
Minneapolis	.71	17.63
Columbus	.64	15.80
Milwaukee	.63	15.54
Kansas City	.62	15.27
Omaha	.62	15.27
Wichita	.62	15.27
Detroit	.59	14.49
Washington, D. C.	.33	7.66
Philadelphia	.26	5.82
New York	.22	4.77
Boston	.15	2.94

Adapted from Table 11.

The low rates from Southern origins may be exaggerated because of the choice of cities used to determine the rate structure. The rates from Birmingham and Charlotte are probably lower than the rates from actual mills in the area would be. No particleboard plants are located in those cities, and large cities typically have lower freight rates due to sheer volume. In contrast the rates for Alamosa and Rapid City are more realistic because these cities are possible plant sites.

Therefore the second phase of the research should include rates for actual locations of particleboard plants in the south to achieve a more realistic rate structure.

Recommendations as to Additional Research Required to Clarify and Expand Knowledge of Particleboard Marketability in Rocky Mountain and Midwest Markets

The conclusions reached so far in this report may be of help in deciding where to locate a plant, but the decision as to what products that plant should manufacture will require a field study of current markets. It is believed that marketing research can add understanding, accuracy, and clarification, based on application of the same scientific research principles that helped to develop the particleboard manufacturing process.

This preliminary study has revealed some encouraging technological information with respect to the potential of Rocky Mountain species for the production of particleboard but a definite lack of published information on markets: who uses particleboard; how it is obtained; why it is used; how it is used; how rates of use differ between kinds of customers; the quantity and scheduling demands that must be met for different users; how much is purchased at one time; customer attitudes toward particleboard; characteristics of the product most important for enhancing product loyalty; the sales potential in each geographic location for each product and end-use;

distribution channels most effective for serving different clientele, etc. The list goes on and on. By careful searching of the available literature it may be possible to find at least partial answers to some of these questions; but if one is going to develop an effective marketing program, it will have to be based on more than partial answers (Bruce, 1970).

Future research is needed to answer some of the questions uncovered or only partially answered by this preliminary investigation. This research should involve the augmentation of existing data, the collection of new data, and the synthesis of existing and new data for the purpose of estimating future markets.

More specifically, additional data are needed on the ranges of board properties that may feasibly be obtained through the use of the study species. Such information may be acquired in part from manufacturers of commercial boards but, where not obtainable from this source, should be acquired through controlled laboratory manufacture and testing. The upper and lower critical densities of boards made from the study species, as well as from major competing species, should be determined so that products for which Rocky Mountain species have a technical capability or advantage may be more clearly identified.

New data on potential production and prospective markets should be obtained by means of appropriate interviews with individuals and organizations knowledgeable on these subjects and/or a sample survey of the trade area.

Data should be collected to show:

1. The structure, conduct, and performance of existing and currently planned particleboard markets in the defined market areas.
2. An estimate of the volumes presently consumed in the defined market areas by type and end use.

3. Price and other competitive factors relative to alternative materials.

Based on the new data, historical data, and predictions of future economic activity, projected trends in consumption of particleboard should be estimated through 1985. Separate estimates should be made for each of the following:

1. Construction: residential, non-residential, repairs and remodeling.
2. Manufacturing: modular (factory-built) homes, mobile homes, household furniture, kitchen cabinets, non-residential furniture, partitions and fixtures, general manufacturing, and recreation vehicles.

Also widely used specifications and model code requirements for particleboard should be studied, summarized and evaluated, including specific examples.

The adequacy of the definition of the Rocky Mountain and Midwest areas that appear to be the best markets for Rocky Mountain producers particleboard should be reviewed.

The transportation advantages and disadvantages of Rocky Mountain producers with respect to West Coast, Southern, and Lake States producers in shipments to the market territories as defined in this report should be reviewed and expanded. Truck transportation rates and additional rail transportation rates should be gathered as deemed necessary.

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APPENDICES

APPENDIX A

Rates from ALAMOSA, COLORADO to Destinations shown by Rail Carload

Rates are given in cents per cwt.

Destination	34,000#	45,000#	50,000#	65,000#	70,000#	90,000#
Boston			See Note A			
Chicago	139		112			
Columbus			See Note B			
Denver		36		28		24
Des Moines	127		102			
Detroit			See Note C			
Kansas City	106		85			
Milwaukee	139				130	
Minneapolis	139		112			
New York City			See Note D			
Omaha	106		85			
Philadelphia			See Note E			
St. Louis	133		106			
Washington			See Note F			
Wichita	106		85			

Note A: Combination over Chicago-112 (60M) plus 91¢ (60M) or 203
58¢ on excess over 60,000#*

Note B: Combination over Danville-112 (60M) plus 39¢ (60M) or 151
21¢ on excess over 60,000#*

Note C: Combination over Chicago-112 (60M) plus 41¢ (60M) or 153
22¢ on excess over 60,000#*

Note D: Combination over Danville-112 (60M) plus 84¢ (60M) or 196
54¢ on excess over 60,000#*

Note E: Combination over Danville-112 (60M) plus 80¢ (60M) or 192
50¢ on excess over 60,000#*

Note F: Combination over Danville-112 (60M) plus 73¢ (60M) or 185
45¢ on excess over 60,000#*

* These figures on Excess apply only on movement from Chicago

APPENDIX B

Rates from BIRMINGHAM, ALABAMA to Destinations shown by Rail Carload

Rates are given in cents per cwt.

Destination	40,000#	60,000#	90,000#	Rates in Excess over 60M	
Boston		114		68	
Chicago		72		45	
Columbus		63		37	
Denver	156				
Des Moines	122				
Detroit		78		48	
Kansas City	112				
Milwaukee		78		48	
Minneapolis	134				
New York City		97		60	
Omaha	128				
Philadelphia		90		67	
St. Louis	57	51	42	35	See Note
Washington	73	59	52	42	See Note
Wichita	128				

St. Louis Note:	Excess over 40,000#	41
	Excess over 60,000#	35
	Excess over 90,000#	30
Washington Note:	Excess over 40,000#	53
	Excess over 60,000#	42
	Excess over 90,000#	35

APPENDIX C

Rates from CHARLOTTE, N. C. to Destinations shown by Rail Carload

Rates are given in cents per cwt.

Destination	40,000#	60,000#	90,000#	Rates in Excess over 60M	
Boston		84		55	
Chicago		84		55	
Columbus		67		40	
Denver	194				
Des Moines	143				
Detroit		80		48	
Kansas City	141				
Milwaukee		92		58	
Minneapolis	155				
New York City		71		43	
Omaha	155				
Philadelphia		64		37	
St. Louis	76	64	56	46	See Note
Washington	45	41	35	29	See Note
Wichita	155				

St. Louis Note:	Excess over 40,000#	54
	Excess over 60,000#	46
	Excess over 90,000#	38
Washington Note:	Excess over 40,000#	32
	Excess over 60,000#	29
	Excess over 90,000#	23

APPENDIX D

Rates from PORTLAND, OREGON to Destinations shown by Rail Carload

Rates are given in cents per cwt.

Destination	Rate	Code
Boston	218	2
Chicago	193	1
Columbus	215	2
Denver	128	3
Des Moines	185	1
Detroit	212	2
Kansas City	147	3
Milwaukee	193	1
Minneapolis	183	1
New York City	218	2
Omaha	147	3
Philadelphia	218	2
St. Louis	187	1
Washington	218	2
Wichita	147	3

Code:		Closed Cars	Minimum Weight
	1	Not over 36'	38,000#
		36' to 42'	44,000#
		Over 42'	54,000#
	2	Not over 40'7"	50,000#
		40'7" to 52'6"	60,000#
		52'6" to 60'10"	72,000#
	3	Up to 40'7"	40,000#
		40'7" to 42'	44,000#
		42' to 52'6"	50,000#
		Over 52'6"	60,000#

APPENDIX E

Rates from RAPID CITY to Destinations shown by Rail Carload

Rates are given in cents per cwt.

Destination	36,000#	50,000#
Boston	See Note A	
Chicago	136	108
Columbus	See Note B	
Denver	73	62
Des Moines	92	73
Detroit	See Note C	
Kansas City	108	86
Milwaukee	133	106
Minneapolis	92	73
New York City	See Note D	
Omaha	83	67
Philadelphia	See Note E	
St. Louis	143	114
Washington	See Note F	
Wichita	112	91

Note A: Combination over Dubuque - 81¢ (60M) plus 103 (60M) or 184
59¢ on excess over 60,000#*

Note B: Combination over Dubuque - 81¢ (60M) plus 61 (60M) or 142
23¢ on excess over 60,000#*

Note C: Combination over Dubuque - 81¢ (60M) plus 58¢ (60M) or 139
30¢ on excess over 60,000#*

Note D: Combination over Dubuque - 81¢ (60M) plus 99¢ (60M) or 180
57¢ on excess over 60,000#*

Note E: Combination over Dubuque - 81¢ (60M) plus 94¢ (60M) or 175
54¢ on excess over 60,000#*

Note F; Combination over Dubuque - 81¢ (60M) plus 88¢ (60M) or 169
52¢ on excess over 60,000#*

* These figures on Excess apply only on movement from Dubuque